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Scaffolding language in multilingual mathematics classrooms

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Table of contents

Voor Arthur, Abel en Adinda

Chapter 1

Introduction

Introduction

It is essentially in the discourse between teacher and students that education is done, or fails to be done. (Edwards & Mercer, 1987, p. 101)

1.1 Positioning the PhD study

In many countries, numbers of migrants are increasing, and classroom populations change accordingly (Elbers, 2010). As a consequence, teachers face the challenge of teaching in classrooms with pupils of various backgrounds (e.g., Echevarria, Vogt, & Short, 2008). In most schools, however, this challenge is not sufficiently met: International pupil achievement studies show the lack of success in educating linguistically and culturally diverse populations worldwide. The Programme for International Student Assessment (PISA), for instance, has revealed that in many countries immigrant[1] pupils (both first and second generation) perform significantly worse on literacy and mathematics than their native peers (Gille, Loijens, Noijons, & Zwitser, 2010; OECD, 2003, 2004; Schleicher, 2006). Such studies urge policymakers and researchers to support teachers and schools in adapting to the new circumstances in order to provide immigrant pupils with better educational opportunities (Walqui & Van Lier, 2010).

In this thesis we address the diversity challenge for the key school subject of mathematics. This challenge is multifaceted: Different forms of diversity, such as socio-economic, cultural and linguistic diversities have been found to influence mathematical attainment (Artigue, 2012; Barwell, 2012; Gorgorió & Planas, 2001). In line with Van Eerde and Hajer (2009) we focus on how teachers can linguistically support pupils who learn mathematics in a language that is not their first language. There are classrooms with a homogeneous population of immigrant pupils (e.g., Latino populations in US classrooms) taught by teachers who speak both the language of instruction as well as immigrant pupils' main language. The Dutch situation is different: Diverse classrooms typically involve more than one language other than the language of instruction (e.g., Moroccan-Arabic, Berber and Turkish), and for most teachers these languages are foreign languages. As a consequence, it is not feasible for teachers in the Dutch context to draw on immigrant pupils' main languages for developing mathematical language (such *code-switching* is investigated, for instance, by Setati, Adler, Reed, & Bapoo, 2002). In almost all schools only the Dutch language can be used to support multilingual pupils' proficiency in subject-specific language so they can become productive members of mathematics classrooms and, later on, society (cf. Gibbons, 2009; Schleppegrell, 2007). Native pupils, whose main language *is* the language of instruction, also benefit from such an explicit focus on subject-specific language (e.g., Adler, 1999; Morgan, 2007). Given this background, we aimed to provide scientifically grounded insight into how language-oriented mathematics education can be designed, enacted and evaluated.

Over the past decades, the relation between mathematics and language has been described and investigated by many scholars from a variety of theoretical perspectives (Moschkovich, 2010). Although learning mathematics involves understanding and using multiple semiotic systems, such as symbols and visual representations, language has recently been argued to be the most prominent of these systems (Schleppegrell, 2007). Scholars in this research field take different theoretical orientations (e.g., constructivist, semiotic, or sociocultural), but they share the assumption that learning mathematics involves more than just learning mathematical vocabulary (e.g., Morgan, 2005; Moschkovich, 2002). In order to fully participate in mathematics lessons, pupils need access to mathematical discourse in a broader sense; they need to get induced into new ways of using language (Lee, 2006; Moschkovich 2010; Prenger, 2005; Van Eerde & Hajer, 2009). Daily language is not to be avoided in this process (Barwell, Leung, Morgan, & Street, 2005; Forman, 1996; Moschkovich, 2010), as it is a fundamental basis for the development of such subject-specific content language (also referred to as *mathematical register* or *mathematics register*, cf. Halliday, 1978; Pimm, 1987). For realising our aim of promoting pupils' language development for mathematical learning, we draw on sociocultural and content-based learning theories, which are elaborated in the next sections.

Sociocultural theory, originating in Vygotsky's (1934/1962; 1930/1978) work, provides a suitable theoretical lens for studying topics related to diversity (Elbers, 2010; Lim & Renshaw, 2001; Torres-Velásquez, 2000). We describe core ideas of sociocultural theory that are relevant within this thesis, the influence of sociocultural theory on mathematics education reform, and the sociocultural shift in the field of second language learning. Content-based second language teaching (Brinton, Snow, & Wesche, 1989, 2003; Gibbons, 2009) is subsequently characterised in international and national perspective. We make a connection with the theory of realistic mathematics education (Freudenthal, 1991; Gravemeijer, 1994; Van den Heuvel-Panhuizen, 1996) which informed Dutch mathematics education, and we also sketch the current problems and challenges in Dutch multilingual mathematics classrooms. Then we identify the knowledge gap and introduce the concept of *scaffolding* (Gibbons, 2002; Wood, Bruner, & Ross, 1976), which is central to this thesis. The main research question is formulated towards the end of the theoretical background.

In a subsequent section we characterise the methodological approach of this study. In the last section, we present how various aspects of the main research question are addressed in the articles that form the core of this thesis. In doing so, we clarify the structure of this thesis.

1.2 Sociocultural theory informing this study

1.2.1 Vygotsky and the study of human development

Views on how children learn and develop have undergone many changes. A crucial change was the emergence of sociocultural theory, for which Vygotsky's revolutionary ideas (1962, 1978) form the basis. Vygotsky aimed to develop a methodology for the study of human development, and in particular the study of what he called *higher mental functions*. Wertsch (1985) identified three recurring themes in Vygotsky's writings that are closely related to ideas of his contemporaries in Russia. First, genetic analysis in a variety of domains is needed to understand psychological phenomena. In such analysis, the origins and history of these phenomena are examined. Secondly, higher mental functions are created by social processes. Thus, to understand inner mental processes (e.g., thinking), one has to look at human beings in their sociocultural context. Thirdly, all activity, including thinking, is mediated by cultural tools (such as language) and signs.

What was revolutionary about Vygotsky's ideas was first his focus on the social rather than the individual for explaining human intellectual growth. At the time Vygotsky's ideas reached western psychology at a larger scale (from 1962 onwards, when *Thought and Language* was published in English), the Piagetian thesis that human intellectual growth results from the direct interaction between the individual as a lone scientist (Alexander, 2008) and the world was predominant. Vygotsky's developmental theory contradicted this widespread viewpoint in that it stressed the role of joint activity (e.g., social interaction) in the construction of knowledge. Sfard (1998) referred to these contradicting viewpoints in terms of two well-known and widely employed metaphors for learning: the acquisition and the participation metaphor. From an acquisitionist perspective, human development is the result of acquiring knowledge, related to the biological capacities of an individual. From a participationist perspective, human development results from engaging in social, collective activities. Here, the individual is seen as a participator or an apprentice, appropriating societal or collective knowledge when participating in social contexts (Rogoff & Lave, 1984; Van Oers, 1996).

A second innovative element in Vygotsky's ideas is the critical role of the parent or teacher as a *more knowledgeable other* (1978), who could lead children on to new levels of conceptual understanding (e.g., Edwards & Mercer, 1987; Wertsch, 1991). Closely related to this notion of more knowledgeable other is the concept of *zone of proximal development* (ZPD; 1978), which is considered the core concept of Vygotsky's developmental psychology. Although interpreted in various ways (see Chapter 4), the concept of ZPD has most often been used to refer to a metaphorical space where learning takes place (Litowitz, 1993). This process of learning involves at least two persons, one of whom is more knowledgeable. As described by Lantolf and Poehner (2011), it is the ZPD that

constitutes a framework for the teacher to diagnose pupils' abilities and at the same time an orienting basis for interventions to support their development.

A third key element in Vygotsky's writings was the role attributed to language. Vygotsky described two main functions of language: first, as a communicative or cultural tool, used for the collaborative construction and sharing of knowledge; secondly, as a psychological tool, used for individual thought and reflection. The combination of language and thought was to create a cognitive tool for human development. Vygotsky (1931, cited in Daniels, Cole, & Wertsch, 2007, pp. 53-54) formulated it as follows:

> Every function in the cultural development of the child appears on the stage twice, in two planes, first, the social, then the psychological, first between people as an intermental category, then within the child as an intramental category.

The process by which intermental becomes intramental is called *interiorisation* (Meshcheryakov, 2007, p. 165). Vygotsky presumed an individual to shape his or her own thoughts in joint activity with others. As Van Oers (2006) wrote: "The psychological itself ís a social phenomenon" (p. 118). Vygotsky further presumed the others taking part to be shaped by this joint activity. This explains how collective understanding is created by individuals (Mercer & Howe, 2012).

1.2.2 The focus on classroom talk

Although Vygotsky's primary focus was on psychology, his ideas have had a major impact on educational research. The core ideas of both thinking as an "individualised version of interpersonal communication" (Sfard, 2008, p. 81) and of dialogue between experts and novices being crucial for cognitive development, have increasingly led to classroom talk as focus of educational studies (e.g., Cazden, 2001; Hicks, 1996). The application and elaboration of new concepts and instructional frameworks have been the result. Widely employed in studies on classroom interaction is the aforementioned concept of scaffolding (introduced by Wood, Bruner, & Ross, 1976), mostly described as a particular kind of help provided by a teacher to help a pupil move forward in the ZPD. Furthermore, socioculturally informed instructional frameworks have arisen, such as reciprocal teaching (Palincsar & Brown, 1984) and assisted performance (Tharp & Gallimore, 1988), both specifying the assisting role of the teacher in supporting pupils' learning (cf. Daniels, 2007). A relatively recent trend is the growing emphasis on dialogic forms of instruction, including approaches of dialogic teaching and dialogic inquiry (e.g., Alexander, 2008; Wells, 1999). Extensive research conducted by Mercer and Littleton (2007) has yielded evidence that pupils' engagement in particular kinds of classroom interaction (e.g., exploratory talk in which the teacher offers specific guidance) can indeed support pupils' reasoning skills and academic performance.

Researchers' focus on classroom talk as central to pupils' development has also induced the development of new qualitative methodologies, which enabled researchers to closely investigate interaction processes taking place in the classroom (as noted by Daniels, Cole, & Wertsch, 2007). Numerous studies have investigated teachers' verbal assistance to pupils, often focusing on interactive teacher strategies or teacher questions (e.g., Edwards & Mercer, 1987; Franke et al., 2009; Nathan & Kim, 2009), which from a sociocultural perspective are considered linguistic tools that mediate and assist pupils' mental activity. Another main research strand has particularly focused on patterns of classroom talk between teachers and pupils. One very common and pervasive teacher-pupil interaction pattern, that is characteristic for classroom instruction all over the world (Gibbons, 2009; Stone, 1998), is the three-part structure labelled as Initiation-Response-Evaluation (IRE; Mehan, 1979): a teacher initiation, a pupil response and a teacher evaluation (also referred to as IRF: Initiation-Response-Feedback; e.g., Wells, 1993). An example Gibbons (2002, p. 16) gives, is:

> Teacher: "What season comes after fall?"
> Pupil: "Winter."
> Teacher: "Good girl."

This IRE pattern has been criticised for simply testing pupils' knowledge (Cazden, 2001), as the first question is by nature one to which the teacher already knows the answer. Moreover, the IRE sequence has been argued to constrain pupils from collaborating, negotiating meaning and elaborating their ideas (Wolf, Crosson & Resnick, 2005). Pupils, being well aware of the scripted type of classroom interaction, focus on giving the right answer rather than on voicing opinions and ideas (Cobb & Yackel, 1996). Over the years, many scholars have investigated ways of extending the IRE sequence (e.g., Gibbons, 2002; Mercer 1995; Nassaji & Wells, 2000) in an attempt to enrich classroom talk. Some have explicitly related the IRE pattern to unequal and asymmetrical roles of teachers and pupils, and advocated democratising the classroom (e.g., Damhuis, 2000; Hajer, 2000; Zhang Waring, 2009). For multilingual pupils the predominance of the IRE pattern is particularly problematic, because, to develop proficiency in the second language, they need ample opportunities for language production that have a more exploratory and elaborate nature (Boyd & Maloof, 2000; Canale & Swain, 1980).

1.2.3 Sociocultural theory as a guiding framework for mathematics education reform

Along with constructivism and socioconstructivism, sociocultural theory has yielded new and distinct beliefs about teaching and learning (Cazden, 2001; Cobb & Yackel, 1996). Forman (2003) described two Vygotskyan ideas that are at the core of mathematics reform. The first idea is the joint construction of knowledge in which the

mediating role of spoken language is central. The second general idea concerns the fundamental relation between instructional practices (including the roles of teachers and learners) and pupils' learning processes. The ideas come to the fore in the often cited standards for mathematics teaching, published by the National Council of Teachers of Mathematics (NCTM, 2000).

Exemplifying reform efforts in mathematics education, these NCTM standards suggested a shift away from teacher-centred, IRE-dominated, as well as procedure- and computation-oriented mathematics classrooms, towards classrooms as mathematical communities in which classroom discourse receives major attention. More specifically, NCTM advocated a shift towards classroom discourse in which mathematical concepts could be shared and investigated, and in which mathematical reasoning (rather than merely memorising procedures) would be central. Actively participating in mathematical discourse was regarded as key to the development of mathematical understanding. A dual benefit of pupils' communicating in the mathematics classroom was formulated as: "They communicate to learn mathematics and they learn to communicate mathematically" (NCTM, 2000, p. 60).

The teacher's role, instead of the traditionally envisioned transmitter of knowledge, was to support and promote mathematically productive discourse (Lampert & Cobb, 2003; Van Oers, 2001) in a variety of settings (e.g., small group and whole-class settings). To this end, a number of desirable teacher behaviours have been described (NCTM, 2000). These include asking pupils to justify their ideas orally and in writing, as well as monitoring pupils' participation in discussions and deciding when and how to encourage pupils to participate. Pupils, too, were to fulfil a different role. They should be allowed and encouraged to take a more active role in classroom discourse, for instance by initiating and providing feedback (see also Cobb, Wood, & Yackel, 1993). Several scholars have paid specific attention to social and sociomathematical norms that need to be established to realise such reform teacher and learner roles (Forman, 2003; Gorgorió & Planas, 2001; Lee, 2006; Yackel & Cobb, 1996). For instance, pupils' contributions to classroom discourse must be treated seriously, both by the teacher and by other pupils, and treated as relevant and important for others. Much attention is paid to explaining, justifying, listening, asking, challenging and trying to understand each other's contributions.

If pupils are to participate actively in mathematical discourse, the use of language becomes central to mathematical learning. Forman (1996) viewed mathematical learning as apprenticeship into the discourse and reasoning practices of mathematically literate adults. She argued that the mathematical discourse that pupils are to master is a

specialised type of language. Pupils thus need opportunities for initiating topics, providing explanations, debating and negotiating issues (e.g., Lampert, 1989), as well as opportunities for becoming fluent in the subject-specific types of language needed for mathematical learning in particular domains. It is for the teacher to facilitate these opportunities. However, as Lampert and colleagues (1996) argued, the NCTM standards insufficiently describe what exactly teachers need to do in order to create such opportunities in *spoken interaction*. Doerr and Chandler-Olcott (2009) noted that the standards do not address how pupils can be deliberately supported in developing proficiency in mathematical *writing* either. They stressed that this omission is particularly problematic for second-language learners.

Interventionist research investigating language learning opportunities in mathematics education is scarce (Moschkovich, 2010). We thus need investigations into teacher instruction that will support specialised talk and writing in mathematics lessons (Lampert & Cobb, 2003). Some scholars have suggested using genre instruction to attend to specialised forms of talking and writing in mathematics education (e.g., Mousley & Marks, 1991). Such instruction, characterised as an "explicit pedagogy for inclusion and access" (Cope & Kalantzis, 1993, p. 64), explicitly attends to goals and features of particular text types (or genres; see Chapter 3).

Despite many efforts in research and practice to promote reform in mathematics education, many mathematics classrooms still hold a traditional and teacher-dominant nature, in which there is little or no room for mathematical discourse (Lampert & Cobb, 2003). Webb, Nemer, and Ing (2006) even found reform-oriented classrooms to demonstrate a lack of pupil contributions and a scarcity of teacher queries eliciting elaborate answers or mathematical reasoning. Thus, many aspects of reform mathematics education still need to be explored and promoted, if we are to establish classroom cultures in which language is viewed and used as integral to doing mathematics (McCrone, 2005).

1.2.4 Studying second language learning from a sociocultural perspective

Sociocultural theory has not only informed educational reform movements, but has also influenced current conceptions of learning in a variety of disciplines. One such discipline relevant within this thesis is the field of second language learning (also referred to as second language acquisition). Two hypotheses dominated this field before a shift toward a sociocultural frame of reference took place. The first was the comprehensible input hypothesis (Krashen, 1982): providing comprehensible input in oral and written texts is the sufficient condition for promoting the cognitive mechanisms that result in second language acquisition. This hypothesis confined second

language acquisition research to the question of how input could be made comprehensible, yet without simplifying language. In an attempt to broaden this rather narrow focus of research, Swain (1985) formulated the comprehensible output hypothesis: second language acquisition requires learners' output (use) of second language. This output had to involve participating in extended interactions, so that pupils had ample opportunity to use the target language in elaborate ways. Swain presumed language output to push learners to process language more deeply than input would do (e.g., by noticing particular language forms during the actual use of language).

Recently, however, both the terms *input* and *output* have been criticised for representing the view of language as a conduit, as something that can be transmitted to individuals (as noted by Swain, 2000), rather than viewing language as a system in which meanings are jointly constructed by the users (Hall & Verplaetse, 2000; Hammond, 2001). Scholars adhering to the latter view of language as a social meaning-making system emphasise how social interaction provides the conditions that will promote second language learning. Gibbons (2009), for instance, described how failing communication can urge second language learners to "stretch" their language skills at the "outer boundaries" of the ZPD (p. 134). She further emphasised that meanings are not fixed, and that pupils' second language learning is also promoted by negotiation of meaning in social interaction. Dixon et al. (2012) concluded from a large review study that approaches to second language learning have shifted attention from linguistic correctness to a concern with appropriateness – that is to say, appropriate language use for particular social and cultural contexts. Thus, the scope of research on second language learning has now moved beyond the output hypothesis to a more sociocultural frame of reference: the social interactive settings themselves are presumed to foster development in the second language (Swain, 2000).

Hall and Verplaetse (2000, p. 10) articulated the role of classroom discourse in this sociocultural perspective on second language learning as follows:

> Given the significant role of classroom discourse in learning, and given that oral communication is both the medium of learning and an object of pedagogical attention in the second and foreign learning classrooms, the role of classroom discourse in additional language learning is especially important.

As a consequence of this perspective, the roles of teacher and learners, the goal of second language learning and the strategies used all change (Dixon et al., 2012). A sociocultural perspective on second language learning also entails the use of more holistic qualitative methodologies (Lantolf, 2000). As has proven to be the case for the influence of particular kinds of social interaction on intellectual development (Mercer & Littleton, 2007), there is

also research evidence that social interaction can have a positive impact on second language learning (e.g., Ellis, Tanaka, & Yamazaki, 1994; Van den Branden, 1995).

1.3 Content-based second language teaching

1.3.1 An international perspective

The view of social interaction being crucial for second language learning is well compatible with a pedagogy that was introduced as content-based language instruction (Brinton, Snow, & Wesche, 1989, 2003; Snow & Brinton, 1997), also referred to as the content-based approach (e.g., Hajer, 2000), or content-based second language teaching (e.g., Knežić, 2011). The original term of content-based language instruction has been used as an "umbrella term" (Stoller, 2008, p. 59), referring to instructional approaches that focus on content *and* language learning, though not necessarily in equal ways (Elbers, 2011). We use the notion of content-based second language teaching to refer to the teaching of subject matter in subject classes wherein the teaching of second language is integrated. Davison and Williams (2001) distinguish a continuum from more language-driven to more content-driven instructional approaches: language teaching, contextualised language teaching, simultaneous integrated language and content teaching, language conscious content teaching, content teaching (pp. 58-59). The approach to content-based second language teaching as envisioned in this study comes closest to simultaneous integrated language and content teaching.

Content-based second language teaching draws on the view that the regular content classroom provides optimal opportunities for learning a second language (Lyster, 2007). The idea of integration content and language teaching was new at the time this approach was formulated (in the 1980s). Before that time, second language teaching was carried out separately from teaching curriculum knowledge (focusing in particular on grammatical structures and language functions) and outside the content classroom, both in the Netherlands (Hajer, Meestringa, & Miedema, 2000) and internationally (Gibbons, 2002; Snow, Met, & Genesee, 1989). In this way pupils missed the chance to develop the second language in a meaningful way, namely as integral to developing content knowledge. From a sociocultural perspective, pupils missed the chance of *apprenticeship* (cf. Gibbons, 2002) – to learn the second language as part of a particular cultural and social context (e.g., a mathematics classroom). Moreover, non-integrated approaches proved insufficient to help pupils succeed in mainstream classrooms (Richards & Hurley, 1990). Content-based language instruction emerged from the need to bridge the gap between pupils' second langage learning in so-called reception classes and their participation in the mainstream classroom.

The approach of content-based second language teaching is a pedagogical response to the lasting challenge of educating pupils with linguistically diverse backgrounds. These pupils encounter the problem of learning particular school subjects through a language of instruction that they do not yet master (Echevarria, Vogt, & Short, 2008; Elbers, 2010). Within content-based second language teaching, teachers are prepared to teach content effectively while supporting pupils' language development. Lyster (2007, p. 23) described the benefits of content-based classrooms for second language learning as follows:

> Content-based classrooms replicate conditions for sustained exposure and authentic communication more than most other types of second language classrooms, insofar as the target language is used purposefully to study other subjects, thus providing, theoretically at least, classroom settings with optimal conditions for language learning.

A first well-known model of content-based second language teaching, which has proven to contribute significantly to pupils' literacy development, is the model of sheltered instruction (Echevarria, Short, & Powers, 2006; Echevarria, Vogt, & Short, 2008; Short, Echevarria, & Richards-Tutor, 2011). This model, constituting an approach to teach subject area curriculum to pupils who are learning through a second language, describes instructionally effective techniques that make subject matter more accessible to these pupils and also support their development of second language skills.

A second, more recent, model is informed by both sociocultural theory and systemic functional linguistics (Halliday, 1994; see especially Chapter 3 in this thesis): the *teaching and learning cycle* (e.g., Derewianka, 1990; Gibbons, 2002, 2009). This cycle consists of a series of four stages in which a particular text type needed at school is introduced, modelled, jointly practised and eventually individually performed by the pupils. It is to be used in content classrooms (e.g., history, science or mathematics). Underlying this cycle is the idea that pupils need to gradually develop language skills along a mode continuum (Gibbons, 2002) from most *spoken-like* everyday language into *written-like* academic language, bridged by literate spoken language, also referred to as "bridging discourses" (as in Gibbons' book title, 2006). The written-like academic language includes those aspects of the second language that are most relevant to curriculum learning. Valdez, Bunch, Snow, and Lee (2005, p. 127) defined academic language as "the language used in school to learn, speak and write about academic subjects." In fact, it is the academic language that provides access to specialised forms of reasoning that are needed to optimally participate in particular school subjects (Gibbons, 2009). Second language learners, however, do hardly develop academic language proficiency as a by-product of classroom discourse (e.g., Janzen, 2008; Schleppegrell, 2004; Tardy, 2006). Therefore, Gibbons advocated teachers' scaffolding of

language, for which she formulated a large amount of practical advice: interactive strategies, approaches to focusing on language (e.g., the use of metalanguage), and examples of instructional activities to be used in particular stages of the teaching and learning cycle. Gibbons based this normative advice on case studies. Effect studies centralising the influence of academic language promotion on pupils' language development are scarce (an exception is Brown, Ryoo, & Rodriguez, 2009; see Elbers, 2011).

1.3.2 A national perspective on integrating mathematics and second language teaching

In the Netherlands the movement of Language-Sensitive Content Teaching (*Taalgericht Vakonderwijs*; Hajer & Meestringa, 2004) has instigated several attempts to realise content-based second language teaching within particular school subjects. One such school subject is mathematics education (Van Eerde & Hajer; 2009; Van Eerde, Hajer, & Prenger, 2008). As these attempts have been informed by the theory of realistic mathematics education (RME; Freudenthal, 1991) – the theory that also informed the design process in this research – we first outline some of RME's core ideas that are relevant to this thesis. Subsequently, we centralise educational practice of Dutch mathematics classrooms nowadays. Last, we describe the exploratory attempts to realise content-based second language teaching in Dutch mathematics education.

Realistic mathematics education (RME)

The theory of RME considers mathematical learning as a human activity that should be meaningful to pupils. Its emergence in the 1970s was a response to traditional mathematics teaching predominant at that time, in which mathematics was viewed as a ready-made system to be passed on by a teacher to pupils in one-way instruction. In traditional mathematics teaching, the focus tended to be on correct pupil answers as well as on recalling facts and procedures. This way of teaching left pupils unprepared for more complex problem solving. Pupils neither received opportunities to engage in mathematical meaningful activity nor to contribute verbally (as noted, for instance, by Nelissen, 1987). Classroom discussions were scarce; in fact, the dominant role of the teacher was central to this form of mathematics teaching. The emergence of RME in response to this traditional form of mathematics teaching can be viewed as a similar tendency to the above described reform movement as exemplified by the NCTM standards.

Mathematical meaningful activity as central principle of RME refers to pupils' active sense-making of mathematical or contextual situations. Instead of taking formal mathematics as a starting point for mathematics teaching, RME advocates a gradual process of *progressive mathematisation* (Treffers, 1987): the development from intuitive, informal, context-bound notions towards more formal mathematics, with the support

of symbols and models (e.g., a line graph). In line with Freudenthal's (1991) idea of "mathematics starting and staying in reality" (p. 18) the notion *realistic* in RME refers directly to the meaningful situations that form the starting point for such process of progressive mathematisation. Problem situations had to be "experientially real" (Cobb, Yackel, & Wood, 1992, p. 13) for pupils, which in primary classrooms mostly implied that these situations could be encountered in daily life (e.g., the growth of a flower) or in mathematical situations (patterns in numbers). To ensure meaningful activity, the use of pupils' own constructions and productions was advocated as these were supposed to be meaningful to them (Treffers, 1987).

One of the design heuristics central to RME for promoting progressive mathematisation is that of *guided reinvention* (Freudenthal, 1991). This heuristic refers to particular guidance that teachers give to pupils so they can experience the learning of mathematics as a process similar to how mathematics was invented in the past (Gravemeijer, 1994). First, the *instructional design* is to guide the reinvention process. This implies, for instance, to start mathematical activity with open problems that do not yet involve ready-made mathematical models (cf. Van Galen & Oosterwaal, 2009). Moreover, it involves the use of meaningful, rich contexts that promote pupils' solving of mathematical problems as well as their progress toward more formal mathematical activity (Gravemeijer, 2004). Secondly, it is for the *teacher* to guide the reinvention process. The reinvention process involves active pupil participation, and thus the establishment of novel teacher and learner roles. It is not only for the pupils to understand what the teacher says, but also for the teacher to understand what the pupils say (Gravemeijer, 1995, 2008). For such negotiation of meaning to actually happen, a change in classroom norms is needed, to be established by both the teacher and the pupils. This has been addressed in the notions of didactic contract (Brousseau, 1983) and social norms (e.g., Cobb, Wood & Yackel, 1993; Gravemeijer, 1995; Hoek, 2007). There are more design heuristics in RME such as historical and didactical phenomenology (e.g., Bakker & Gravemeijer, 2006) and emergent modelling (Gravemeijer, 1994), but these were not central in our study.

Apart from these heuristics, the theory of RME also offers several tenets (Treffers, 1987). The tenets most central to our study are phenomenological exploration and interactivity. Phenomenological exploration refers to the aforementioned exploration of problem situations so as to set the stage for meaningful mathematical activity and guided reinvention. Our context of multilingual classrooms demands exploration of the language involved. This issue has so far been underemphasised in the RME literature, although Freudenthal (1984, p. 31) envisioned the integrated teaching of mathematics and language as potentially "ideal." Interactivity refers to classroom interaction (small-group or whole-class) as a crucial source for mathematical learning, here for pupils to gain access to each

other's thinking so they can build their own mathematical knowledge. The teacher is to promote pupils' mathematical reasoning during discussions and is thus to provide pupils with opportunities to contribute, as well as to support the verbalisation of their ideas (e.g., Van Eerde & Hajer, 2009). Inevitably, language plays a crucial role in interactivity.

Educational practice in Dutch mathematics classrooms

In line with the worldwide tendency in mathematics education, many mathematics classrooms in the Netherlands still hold a non-discursive nature (Van den Boer, 2003), despite efforts to implement RME in Dutch mathematics education. The TIMSS video study (Hiebert et al., 2003, p. 109) showed that in all seven countries studied the average number of pupil words is very low compared to average number of teacher words. This ratio in Dutch classrooms was not statistically different from that of other countries studied: Australia, Czech Republic, Japan, Hong Kong, United States and Switzerland (p. 110). However, Dutch teachers did spend more time on making real-life connections (p. 85). From small-scale national studies we also know that pupils receive few chances to contribute to discussions, to verbalise ideas or to jointly explore mathematical subject matter (e.g., Van Eerde, Hajer, & Prenger, 2008). Classroom interaction in Dutch mathematics classrooms has been observed to still be IRE-dominated (Van Eerde, Hajer, Koole, & Prenger, 2002), involving numerical rather than language-rich pupil answers.

National achievement studies (e.g., PPON: Jansen, Van der Schoot, & Hemker, 2005) point out that immigrant pupils' mathematics results significantly lag behind those of their native peers. Studies like these also predict that this problem will persist over the years to come. Moreover, multilingual pupils less often take on mathematics as an exam subject, which confines future study and thus career possibilities. Poor mathematics results in diverse classrooms have often been related to the increased linguistic demands posed on second language learners in mathematics classrooms (Prenger, 2005). A common statement is that RME-oriented teaching makes learning mathematics more difficult for multilingual pupils.

Close examination of several Dutch multilingual secondary mathematics classrooms (involving 450 pupils; Van den Boer, 2003), however, has revealed that the problem should be characterised differently. What is often seen as the problem may well be the solution. While acknowledging that multilingual pupils' poor language proficiency indeed hinders the development of content knowledge, Van den Boer uncovered that the real problem relates to teachers' and pupils' use of language-avoiding strategies, as a result of which multilingual pupils' language problem remains hidden and thus underestimated – by both teachers and learners. Teachers hardly centralise key mathematical concepts and spend little time on exploring contexts. Furthermore, teachers simplify their language, and discourage pupils to ask questions or to use elaborate language. Pupils, in turn, appear to

avoid posing questions or demonstrating misunderstanding. Van den Boer therefore argued that the language problem that lies at the core of poor mathematics results can only be resolved if teachers and pupils become more aware of the counterproductive strategies they use and if teacher-pupil interaction is intensified. The latter recommendation is in line with international recommendations for dealing with second language learners in the mainstream classroom, for instance Gibbons' (2002) advice to amplify language rather than to simplify it. Morgan stated for mathematics education: "Simplification or avoidance of specialised language may be seen as a positive strategy to enable learners to access mathematical ideas, but without it, they are denied access to the forms of mathematical knowledge that are most highly valued" (2007, p. 241). In sum, where RME-based or other interactive forms of mathematics education are in the general public sometimes considered the problem for multilingual pupils, we think in line with content-based second language teaching that they are better considered a potential solution.

Attempts to realise content-based second language teaching in RME classrooms

Content-based second language teaching has been argued to be well compatible with core principles of RME (Van Eerde, Hajer, & Prenger, 2008). In the Netherlands the Wisbaak Project (Van Eerde & Hajer, 2009) has been a first attempt to realise content-based second language teaching for mathematics education that is based on RME principles. Exploratory research with specially developed language-oriented teaching materials indeed showed the possibility of simultaneously developing mathematical and linguistic knowledge. However, in regular mathematics lessons the participating teachers fell back in old, more traditional, routines. Furthermore, this project focused on developing and employing language-sensitive instructional activities rather than developing a repertoire of language-sensitive teaching strategies. Another exploratory Dutch research project, in which characteristics of whole-class interaction in RME-oriented classrooms were investigated, revealed that teachers particularly struggled with supporting the development of language required for mathematical learning (Van Eerde, Hajer, & Prenger, 2008).

The results of these studies imply the need for research focusing on teacher strategies that can *support* pupils' development of subject-specific language for mathematical learning. For this to be sustainable, insights into how teachers can learn to employ such strategies are needed as well.

1.4 The knowledge gap addressed in this thesis

To identify the knowledge gap addressed in this thesis, we recapitulate the main points from the previous sections. In the first place, research is needed to gain insight into how teachers can realise "high quality instruction" for language minority pupils (McIntyre et

al., 2010, p. 334), as national and international achievement studies keep pointing to a discrepancy between native and immigrant pupils' academic success. Central to such research should be the question of how to promote second language learning during particular content teaching (in our case mathematics). Second language learning is expected to be enhanced by social interaction with others, and is to be adaptively guided by a *more knowledgeable other* (in our case the teacher). In the second place, mathematics education has the potential for creating such language-learning opportunities, but daily educational practice diverges from what is often advocated. Reform opportunities – instigated by for instance NCTM standards and RME principles – have not been optimally incorporated into the teaching and learning of mathematics. For teachers to successfully enact reform mathematics teaching in multilingual classrooms, investigations are needed into teacher instruction that will support specialised talk and writing in mathematics lessons. In addition, research needs to yield knowledge about preparing teachers for this vital task (cf. Echevarria, Short, & Powers, 2006).

To refer to a specific kind of finely tuned, adaptive and second language-promoting support offered by teachers in whole-class settings, the notion of *scaffolding language* has been employed (e.g., Gibbons, 2002, 2009; Walqui & Van Lier, 2010). The concept of scaffolding, introduced by Wood, Bruner & Ross (1976) to describe a tutor's adaptive help to a child in the context of problem-solving, refers metaphorically to a temporary construction erected to help with the building of another structure and taken away once this structure can stand on its own. Van de Pol (2012) summarises the parallels of scaffolding in construction work and scaffolding in educational research as follows: both are *temporary*, aiming at *independence*; both are meant for *assistance* in an *adaptive* way. Although the metaphor has also been criticised for not precisely capturing the essence of what it refers to (e.g., Rogoff, 1990; Searle, 1984; Stone, 1998), many researchers and teachers have embraced the metaphor over the last decades. For educational researchers drawing on sociocultural perspectives scaffolding has proven to be a valuable concept for studying teacher-pupil interaction in a variety of ways (Van de Pol, Volman, & Beishuizen, 2010). For teachers it perhaps "resonates with their own intuitive conceptions of what it means to intervene successfully in children's learning" (Mercer & Fisher, 1992, p. 342).

Along with its increasing popularity, the scaffolding concept has been applied in a variety of teaching and learning contexts. One such context concerns the content-based second language teaching model and heuristic of the teaching and learning cycle as described above, in which the concept is directed towards supporting (second) language development throughout the different stages of the cycle. Although case studies have indicated that scaffolding language can indeed be a fruitful teaching approach in second language learning content classrooms (Gibbons, 2006), research on the scaffolding of

domain-specific types of language in mathematics has hardly been carried out. Studies that focus on supporting pupils' mathematical writing are also very scarce (exceptions are Chval & Khisty, 2012, and Doerr & Chandler-Olcott, 2009).

Several researchers have expressed the need for studying the scaffolding of language in mathematics education. Some have in fact undertaken efforts to investigate particular aspects of the scaffolding process (e.g., diagnosing; Van Eerde, 1996). In a recent book titled *Language and Mathematics Education* (Moschkovich, 2010) one of the proposed research questions for future research is (p. 160): "How do teachers provide interaction, scaffolding and other supports for learning academic mathematical language?" This is in line with Schleppegrell (2010), who stated in a review chapter on the linguistic challenges in mathematics teaching and learning (p. 94): "We know that mathematics learning benefits from scaffolding through social interaction with a more expert interlocutor, and studies that describe effective interaction of this type are needed at all levels and in all instructional contexts." This statement corresponds with the above recapitulated knowledge gap of how teachers can *support* the development of specialised forms of talk and writing in mathematics education. Capturing well the role of the more knowledgeable other (Hammond, 2001), scaffolding is therefore employed as a key concept for investigating such support in this thesis.

The research question central to this thesis is:

> *How can teachers in multilingual primary classrooms scaffold pupils' language required for mathematical learning?*

1.5 The methodological approach taken in this study

In this section we characterise the methodological approach of this study. Details can be found in Chapters 2 to 5, in particular Chapters 2 and 3.

1.5.1 Design research

Design research is commonly used when researchers aim to develop theories about how to shape particular types of teaching or learning that are not found in existing naturalistic settings. In such situations, the envisioned types of teaching or learning still have to be designed before they can be studied in more detail. Where educational research methods often separate the design process from the evaluation, design research uses the design process to gain insight about how the envisioned types of learning or teaching can be enacted (Bakker & Van Eerde, submitted). As Edelson (2002, p. 107) put it: "an important characteristic of design research is that it eliminates the boundary between design and research."

In this research project, the type of language-oriented mathematics education envisioned was not to be found in naturalistic settings. Neither was it clear at the start of this project, what language proficiency pupils needed to gain access to line graphs, the mathematical domain at stake. Moreover, scaffolding is not commonly observed in classrooms (see e.g., Van de Pol, Volman, & Beishuizen, 2011). Furthermore, very little is known about which interactional strategies a teacher could use so as to scaffold pupils' development of the language required for learning to interpret line graphs.

With so little scientific knowledge to build upon, there was no other way than to study the literature on related fields and use our practical experience to design – in connection with each other – whatever was needed to enact what we had in mind. Such an emergent and holistic approach is typical of design research. This implies that several cycles of preparing, enacting and analysing a teaching experiment were assumed to be necessary. In each cycle, we hoped to formulate more precisely and with better empirical grounding the following issues:

- *Strategies* that teachers could employ to enact scaffolding. We started with about fifty teaching strategies that were mentioned in the literature as potentially assisting in realising language-supportive classroom interaction. We filtered those strategies that we judged as theoretically closest to the concept of scaffolding and that seemed most effective in our context. At the same time, the teacher learned to enact the strategies in increasingly effective ways. This process is analysed in Chapter 2 for the first two design cycles. Chapter 5 provides a repertoire of seven strategies used in the third design cycle.
- The *learning goals*, in particular a description of the language required for learning to reason about line graphs. As Gravemeijer and Cobb (2006) stated, design researchers typically do not take learning goals as a given. In Chapter 3, we describe how we started with the phrase "language required for learning to reason about line graphs" and gradually developed a more precise formulation in terms of a pedagogical genre.
- *Instructional activities*. These activities were designed as stepping stones in the direction of the learning goals. Some activities were inspired by existing instructional activities developed at the Freudenthal Institute for Science and Mathematics Education, Utrecht University, the Netherlands (e.g., Van Galen, 2008). In each design cycle it became easier to formulate the so-called hypothetical learning trajectory (Simon, 1995), which accompanied each lesson (see Chapter 3). Furthermore, we gained progressive insight into employment of the teaching and learning cycle as a design heuristic.
- *Theory of whole-class scaffolding*. Design research intends to develop theory with a broader scope than the specific setting for which the educational activities have been designed. In this research project, we faced the challenge that scaffolding – originally

introduced in one-to-one problem solving situations – was advocated by several scholars for whole-class situations, but used in rather sloppy ways. We therefore saw the need for a more precise and empirically grounded conceptualisation of whole-class scaffolding, which is the topic of Chapter 4.

- *Methods to detect evidence for long-term scaffolding processes.* Another challenge we faced along the way was that most of the available literature studied rather short-term scaffolding processes, whereas our teaching experiments lasted up to nine lessons of one hour. Because second language learning is a long-term process, we needed to develop methods with which we could evaluate whether scaffolding of language had taken place. This challenge is dealt with in Chapter 5.

1.5.2 The domain of line graphs: formulation of RME-informed learning goals

The mathematical content central to the lessons concerned line graphs, a challenging and linguistically oriented domain within mathematics. Internationally, pupils have been observed to experience particular difficulties when interpreting or reasoning about line graphs, which we describe in Chapter 3. Also nationally the results of a periodical investigation of pupils' levels for mathematics in primary education (PPON: Jansen, Van der Schoot, & Hemker, 2005) showed that pupils who have at least one parent from a low-educated, immigrant background performed worse on the subject of line graphs than their native peers.

The formulation of learning goals was informed by several sources:

- text book tasks related to line graphs for identifying which mathematics curriculum knowledge concerning line graphs had been addressed at the start of the teaching experiments;
- key curriculum goals for mathematics as formulated in broad terms in *TULE Kerndoelen* (2007);
- global analysis of test items on line graphs in the CITO assessment (a national standardised test);

and in particular:

- key issues for the domain of line graphs as formulated in the TAL project (Gravemeijer et al., 2007). This RME-informed project carried out at the Freudenthal Institute for Science and Mathematics Education aimed to develop longitudinal learning-teaching trajectories for mathematics education in primary school. We used the TAL descriptions and instructional guidelines for the topic of measurement (related to line graphs).

A summary of the content dealt with in each lesson is provided in Appendix A. Although our research focused on grades 5-6 when pupils are about 10 to 12 years old,

we think – based on the Wisbaak project (pupils aged 10 to 14 years old; Van Eerde & Hajer, 2009) – that the same approach holds in secondary education.

1.5.3 Establishing social norms to make scaffolding language happen

It is known from the research literature that changing a classroom culture cannot be done overnight. The literature on social norms (e.g., Cobb & Yackel, 1996) indicates that new norms have to be established by repeatedly paying attention to aspects of a classroom culture that allow pupils to safely contribute to whole-class interaction. The teacher is to initiate this process and ensure that these norms are established in agreement with pupils. We were thus aware before the first design cycle that we needed to discuss with the participating teacher how to establish the envisioned classroom culture. This was especially important because the participating teacher was substituting the regular class teachers for our interventions. Moreover, a primary condition for a teacher to diagnose and be responsive (as part of the scaffolding process) is that pupils actually talk. To these ends, we took several measures. First, we asked the participating teacher to read several articles on social norms and discussed them with her before the first teaching experiment. In establishing these norms, we provided the teacher with a list of social norms based on different scientific sources (Cobb, Wood & Yackel 1993; Cobb & Yackel, 1996; Gravemeijer, 1995; Hoek, 2007; Mercer & Littleton, 2007). During video-stimulated recall interviews we often discussed how social norms were established, including missed opportunities.

1.6 Structure of the thesis

In this section we elucidate how specific aspects of the main research question are addressed in the articles (Chapters 2-5) that form the core of this thesis. The main research question was formulated as: *How can teachers in multilingual primary classrooms scaffold pupils' language required for mathematical learning?* Table 1 provides an overview of the topics and aims of the various chapters.

In Chapter 2 we address the question of how a teacher participating in dual design research learned to scaffold multilingual pupils' language development required for mathematical learning. Dual design research is introduced as a special case of design research that aims to promote and trace the development not only of the pupils' but also of the teacher's learning (Gravemeijer & Van Eerde, 2009). Chapter 2 addresses this particular question in order to meet two necessary conditions for creating an innovative environment in which scaffolding of language for mathematical learning can take place:

- the need for a teacher who would be able to enact the scaffolding of language;
- the need to further our understanding of how to elaborate and enact scaffolding of language in our particular context.

We presumed that these two conditions would be intertwined. That is, we expected our focus on the teacher's learning to also contribute to our understanding of scaffolding. To answer the question central to Chapter 2, we centralise the following subquestions:

> *2.1 What can a teacher participating in dual design research learn in terms of scaffolding pupils' development of the language required for mathematical learning?*
>
> *2.2 To what characteristics of dual design research can the participating teacher's learning process be attributed?*

In Chapter 3 we address the language that is required for mathematical learning in a particular domain (line graphs). Drawing on genre pedagogy (e.g., Derewianka, 1990; Hyland, 2007), we introduce the notion of *pedagogical genre* to refer to a genre that is deliberately designed for pedagogical purposes – in our case to support pupils' reasoning about line graphs. Developing proficiency in this genre became a central learning goal in our study. Chapter 3 aims to summarise the development of the pedagogical genre that we called *interpretative description of a line graph* and to evaluate what pupils learned from our approach that focused on promoting pupils' proficiency in this pedagogical genre. As such, Chapter 3 not only addresses the nature of the language involved in reasoning about line graphs, but also pupils' language learning processes. The following subquestions are addressed:

> *3.1 To what extent did pupils make progress in deploying the pedagogical genre that we called interpretative description of a line graph?*
>
> *3.2 How can we characterise the development of pupils' genre proficiency?*

To promote proficiency in the targeted pedagogical genre, it was assumed that whole-class scaffolding would be a key thing to pursue.

Chapter 4 presents a conceptualisation of *whole-class scaffolding*. Referring to temporary and adaptive support, the concept of scaffolding has become widely used, also in whole-class settings. However, it has often been used in loose ways: key characteristics of scaffolding have often not been clearly distinguished and even aspects of classroom organisation, artefacts and sequencing have been referred to as scaffolding (overgeneralisation). Chapter 4 deals with these conceptual challenges. The aim of Chapter 4 is to theoretically and empirically ground a conceptualisation of whole-class

scaffolding that stays as close as possible to the spirit of the origin of the scaffolding concept, but that also leaves room for features not salient in one-to-one interaction. The conceptualisation that forms the yield of Chapter 4 includes the following three key characteristics of whole-class scaffolding: diagnosis, responsiveness and handover to independence. These characteristics are argued to be enacted not only *during* but also *outside* whole-class interaction. Apart from this layered nature, whole-class scaffolding also proved to be distributed and cumulative over time. As such, our conceptualisation takes into account the long-term nature of many learning processes (cf. Mercer, 2008).

Chapter 5 addresses the methodological challenges of including pupils' leaning processes (handover) in the analysis of *whole-class scaffolding* as well as to analyse the key characteristics of diagnosis, responsiveness and handover also in relation to each other. An implication of employing the conceptualisation of whole-class scaffolding as we propose in Chapter 4 is our wish to include the long-term nature of whole-class scaffolding in such analysis. We investigate the teacher's use of a repertoire of seven strategies for scaffolding language (e.g., asking for more precise language; reformulating pupils' utterances) that formed one of the yields of the first two teaching experiments. The aim of Chapter 5 is to investigate whether the enactment of strategies intended to scaffold the development of subject-specific language in a multilingual upper primary mathematics classroom indeed led to whole-class scaffolding as identifiable by its key characteristics (diagnosis, responsiveness and handover to independence), taking into account the long-term nature of whole-class scaffolding. To fulfil this aim we address three research questions in response to the aforementioned methodological challenges:

5.1 To what extent did handover to independence take place?

5.2 What evidence of responsiveness can be identified in the teacher's enactment of strategies for promoting language development?

5.3 How are the performed strategies and characteristics (diagnosis, responsiveness and handover) of whole-class scaffolding related over time?

Chapter 6 provides a summary of the main findings followed by a discussion of these findings. The main contributions, limitations, directions for future research as well as implications are discussed.

Table 1 Overview of the chapters of this thesis

Chapter	Title	Focus	Aim	Challenges addressed	Cycles
2	A teacher's learning process in dual design research: Learning to scaffold language in a multilingual mathematics classroom	Empirical and methodological	To investigate how a teacher participating in dual design research learned to scaffold language required for mathematical learning	Involving a teacher in co-designing language-oriented mathematics lessons and enacting strategies intended to scaffold the development of subject-specific language needed for a particular domain (line graphs).	1 and 2
3	Development of a pedagogical genre and evaluation of pupils' genre proficiency: A linguistic turn in educational design?	Theoretical and empirical	To summarise the development of a pedagogical genre and to evaluate what pupils learned from the approach that focused on promoting pupils' proficiency in the pedagogical genre	Thinking through the consequences of a linguistic turn for educational design: to deliberately design a genre as a means of supporting pupils' reasoning about line graphs; To evaluate pupils' proficiency in the pedagogical genre that we called *interpretative description of a line graph*.	1, 2 and 3
4	A conceptualisation of whole-class scaffolding	Theoretical	To theoretically and empirically ground a conceptualisation of whole-class scaffolding	To provide a conceptualisation of whole-class scaffolding that stays as close as possible to the spirit of the origin of the scaffolding concept (i.e. avoiding loose use and overgeneralisation), but that also leaves room for features not salient in one-to-one interaction.	3
5	What counts as evidence for the long-term realisation of whole-class scaffolding?	Methodological and empirical	To investigate whether the enactment of strategies intended to scaffold the development of subject-specific language indeed led to whole-class scaffolding as identifiable by its key characteristics (diagnosis, responsiveness and handover to independence)	To include pupils' learning processes (handover) in the analysis of whole-class scaffolding, to analyse the key characteristics of diagnosis, responsiveness and handover in relation to each other and to include the long-term nature of whole-class scaffolding in the analysis.	3

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Note

1. Terminology about native and immigrant pupils deserves some attention. By native pupils we mean pupils whose first language is the same as the language of instruction (Dutch). Immigrant pupils in our definition speak another language than Dutch at home – here mainly Moroccan-Arabic, Berber or Turkish.

Chapter 2

A teacher's learning process in dual design research: Learning to scaffold language in a multilingual mathematics classroom

This chapter is based on:
Smit, J., & Van Eerde, H. A. A. (2011). A teacher's learning process in dual design research: Learning to scaffold language in a multilingual mathematics classroom. *ZDM: The International Journal on Mathematics Education, 43*(6-7), 889-900.

Abstract

In this paper, we argue that dual design research (DDR) is a fruitful way to promote and trace the development of a mathematics teacher's expertise. We address the question of how a teacher participating in dual design research can learn to scaffold pupils' development of the language required for mathematical learning in multilingual classrooms. Empirical data were collected from two teaching experiments (each with 8 lessons and 21 and 22 pupils, aged 11-12 years), for which lesson series about line graphs were co-designed by the researchers and the teacher. The teacher's learning process was promoted (e.g. by conducting stimulated recall interviews and providing feedback) and traced (e.g. by carrying out 5 pre- and post-interviews before and after the teaching experiments). An analytic framework for teachers' reported and derived learning outcomes was used to analyse pre- and post-interviews. The teacher's learning process was analysed in terms of changes in knowledge and beliefs, changes in practice and intentions for practice. Further analysis showed that this learning process could be attributed to the characteristics of dual design research, for instance the cyclic and interventionist character, the continuous process of prediction and reflection that lies at its heart and the process of co-designing complemented with stimulated recall interviews.

Keywords

Design research · scaffolding language · mathematics teacher's expertise · multilingual classrooms

A teacher's learning process in dual design research: Learning to scaffold language in a multilingual mathematics classroom

2.1 Introduction

Mathematics teachers' expertise can be improved in multiple ways. Teachers can collaborate on improving lessons, such as in lesson studies, with minimal help from outside experts (Stigler & Hiebert, 1999). In contrast, professional development can also be completely expert driven. In between these extremes, there are various forms of collaboration between researchers and teachers that lead to enhanced expertise, such as co-teaching (Roth, Tobin & Zimmermann, 2002), action research (Jaworski, 1998), learning studies (Ling Lo, Marton, Fai Pang & Yan Pong, 2004), teacher development experiments (Simon, 2000), teaching experiments (Norton & McCloskey, 2008) and design research (Brown, 1992; Collins, 1992; Gravemeijer & Cobb, 2006).

When comparing approaches such as lesson studies, learning studies and design research, it is apparent that their core is a process of predicting and reflecting. Secondly, these approaches do not only aim to produce effective lessons, but also to involve teachers in understanding why and how learning processes develop. Thirdly, the professional development activities take place in the context of the classroom. Fourthly, it is believed that only gradual improvement in teaching results in real change. Of course, there are also differences between the approaches. For example, design research as we envision it intends to develop *theory* on innovative forms of learning more explicitly than, say, lesson studies.

In this paper, we argue that design research can be a fruitful environment for mathematics teachers to develop their expertise. So far, very little is known about what and how a teacher can learn from participating in design research. Only a small minority of design research projects focus on *teachers*' learning, for instance by looking at professionalisation of groups of teachers operating in the institutional setting of the schools and district in which they work (Cobb, Zhao & Dean, 2009). The vast majority of design research studies focus on innovative types of learning by *pupils*, and in several cases the teaching is done by experienced researchers (Cobb, 2000). In this type of design research, the teacher's learning is not explicitly investigated. However, if we want teachers to be able to adapt instructional approaches to their own classroom practices, they need to know how these approaches work. To gain insight into such learning processes of teachers, Gravemeijer and Van Eerde (2009) plead in favour of dual design research (DDR), which aims to study the learning of pupils and their teacher within the same study.

Dual design research fits our research topic, scaffolding language development in multilingual mathematics classrooms, for two reasons. Firstly, scaffolding is a relational notion, as it is performed by a *teacher* to promote *pupils*' learning. Secondly, in scaffolding research, the area of scaffolding the *language* that is required for *mathematical* learning still needs development of theory and instructional activities. Therefore, it makes sense to start with small-scale innovative design studies as the basis for larger-scale professional teacher development. Although we investigated pupils' learning processes as well as those of a teacher in our design study, in this paper we focus on the latter. The goal of this paper is to gain insight into how a teacher participating in dual design research can learn to scaffold pupils' development of the language required for mathematical learning in multilingual classrooms.

2.2 Theoretical background

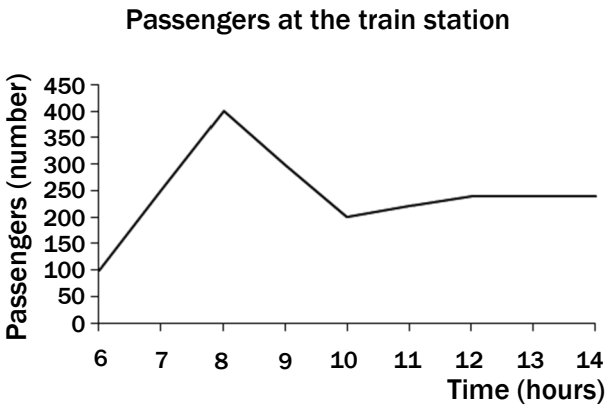
2.2.1 Integrating mathematics and language development

Dealing with ethnic and linguistic diversity is one of the major challenges of today's mathematics education (Campbell, Adams & Davis, 2007; Moschkovich, 2002). A 6-year study in the Netherlands (Van den Boer, 2003) has shown that ineffective teaching and learning practices in multilingual classrooms cause this problem to remain hidden and thus to persist. A common teacher practice is to avoid linguistic aspects of teaching, for instance by decontextualising context problems and avoiding time-consuming verbal interaction. A common pupil practice is to focus on mathematical calculations, considering text and context as of little importance. In addition, pupils tend not to ask questions. There seems to be only one way out of this double bind: to explicitly pay attention to the language needed for mathematical learning.

More generally, approaches of content-based language instruction (Brinton, Snow & Wesche, 2003) argue that teachers throughout the curriculum need to be prepared to teach content effectively *while* developing pupils' language ability. Presumably, such an approach to mathematics education creates opportunities to develop the required content-based (subject-specific) language, as a result of which mathematics lessons can become more accessible for all pupils. In the Netherlands, a few explorative studies have specifically focused on developing such an approach for mathematics (e.g. Van Eerde & Hajer, 2009), but these have had a limited effect: even if teachers learned to give pupils linguistic support, they quickly fell back on old habits. This is hardly surprising, knowing that teachers in the context of educational innovation easily fall back on old routines, even after a considerable period of time and change (Verloop, Van Driel & Meijer, 2001). Hence, an explicit focus on developing teacher expertise for promoting language development in multilingual classrooms is needed.

2.2.2 Scaffolding language

One key strategy to foster language development in multilingual mathematics classrooms is *scaffolding language* (Gibbons, 2002). Drawing on the original definition of scaffolding (Wood, Bruner & Ross, 1976), Gibbons defines scaffolding as temporary, intentional, responsive support that assists second language learners to move towards new skills, concepts or levels of understanding. She places this notion in the context of classroom discourse and argues that bilingual pupils cannot build on the foundations of the second language as can native speakers. To develop the more academic registers necessary for participating in different areas of the curriculum, scaffolding subject-specific language is needed. She argues that education should help pupils to bridge discourses: from their initial most spoken-like (or context-embedded) language to most written-like (or context-reduced) language. The latter mode is presumed necessary to fully participate in a particular school subject. A design heuristic she offers to accomplish this is the 'teaching and learning cycle' (Gibbons, 2009). This cycle consists of a series of four stages in which a particular text type needed at school is introduced, modelled, jointly practised and eventually individually performed.



At 6 o'clock there are about 100 passengers at the train station. Between 6 and 8 o'clock, the number of passengers rises, for the graph shows a steep increase. At 8 o'clock, the number of passengers gets to its maximum: about 400. After that time, till 10 o'clock, the number of passengers drops. The graph descends. After 10 o'clock the number of passengers slowly rises again; the graph shows a gradual increase. After 12 o'clock the number of passengers stays more or less the same. You can tell as the graph is constant.

Figure 1 Line graph and example of a written target text

For this study, we identified a text type, a so-called "target text", for the mathematical domain of line graphs, namely the *interpretative description of a line graph* (Fig. 1). Throughout all stages of the teaching and learning cycle, the teacher can perform *designed* scaffolding strategies (planned support) and *interactional* scaffolding strategies (unplanned support). Examples of designed scaffolding strategies include using a subject-specific word list, a writing plan for pupils, as well as modelling exercises that scaffold the pupils towards understanding the purpose, overall structure and language features of the chosen target text. Examples of interactional scaffolding strategies include repeating correct subject-specific utterances and reshaping what pupils say or suggest writing down.

2.2.3 Required expertise

Judgement of which scaffolding strategies to use in which situations requires a particular expertise. In the teaching literature, it is very common to conceptualise teacher expertise in terms of pedagogical content knowledge (Shulman, 1987), and modifications of pedagogical content knowledge, such as *knowledge of content and teaching* (Ball, Thames & Phelps, 2008). However, many scholars studying pedagogical content knowledge stress its lack of definition and empirical foundation (Ball et al., 2008; Graeber & Tirosh, 2008). In line with Mason (1998), we find it more useful to focus on *awareness* as a starting point for a teacher who is learning, in our case to scaffold. According to Mason, awareness is manifested in alterations in the structure of a teacher's attention. In the context of our research, this implies that the ability to shift attention between the main *foci* – here mathematics *and* the language needed for mathematical learning – represents a certain awareness that is needed to actually realise scaffolding. Of the three layers of awareness Mason distinguishes, *awareness-in-action* best fits our study, because it is the type of awareness that makes certain actions possible.

Based on the literature (e.g. Mason, 2010), we assume awareness to be interrelated with intentions, emotions, knowledge and beliefs. Awareness of pupils' linguistic problems seems to be a basis for the intention and desire to scaffold pupils, but these are also based on the belief that it is possible to do so. Enacting scaffolding requires sensitivity to pupils, which Potari and Jaworski (2002, pp. 352-353) define as "the teacher's knowledge of pupils and attention to their needs." Such enactment requires knowledge of scaffolding strategies and of the conditions for, and consequences of, applying them. Such diagnostic and responsive knowledge we assume, in turn, increases teachers' awareness of pupils' linguistic problems. However, awareness as part of teacher expertise is difficult to operationalise. For these reasons, we propose to include attention to knowledge, beliefs, intentions and emotions in our analysis of teachers' developing expertise.

2.2.4 Our approach to developing teacher expertise

As noted by Bakkenes, Vermunt and Wubbels (2010), several types of learning activities keep returning in the literature on developing teacher expertise:

1. learning by experimenting (e.g. trying out a new teaching method; making new materials);
2. learning in interaction with others (other teachers, researchers);
3. using external sources (e.g. publications);
4. consciously reflecting on one's own teaching practices.

Reflection is frequently mentioned as crucial for expertise development (Ropo, 2004). Revans (1982) argues that reflection implies looking forward as much as backward. It means asking questions about one's own practice and foreseeing possibilities for change and development.

Any approach to developing teacher expertise should thus capitalise on these four teacher learning activities, and many of the approaches to developing teacher expertise mentioned in our introduction indeed do. In the remainder of this section, we explain how we stimulated these learning activities by involving a teacher in our design research project, and why we chose dual design research as the method suitable for our research purpose of gaining insight into how scaffolding can be performed and learned.

By involving the teacher in design research, she was not only experimenting in the classroom (1), but also interacting with us as the researchers (2). In this co-design process, we provided her with external sources (3) such as aforementioned key publications about scaffolding and linguistic problems in multilingual classrooms. As we explain in more detail in Section 2.3, we used the co-design process in combination with stimulated recall interviews (Meijer, Zanting & Verloop, 2002) to promote reflection (4).

Our arguments for using design research are as follows. In line with our research purpose, design research as envisioned by Cobb et al. (2003) aims at developing innovative materials *and* theories. Scaffolding language is not typically done in current mathematics classrooms. Enacting it requires an educational innovation that should in our eyes be accompanied by the development of new theories – layered from insights into what pupils learn from scaffolding strategies that can be performed to insights into how a teacher can learn to perform these strategies. Whereas in lesson and learning studies, for example, the main goal is to achieve particular educational objectives, our initial main focus was the theoretical grounding of scaffolding. Because we did not exactly know at the start of the research project how a teacher could scaffold language in mathematics classrooms, we initially worked intensively with one expert teacher.

Furthermore, the different layers of theory development in design research fit our research purposes well. As design research studies ways to support learning, it allows us to develop theoretically the notion of scaffolding while at the same time enhancing and developing its enactment in real classroom situations. In the case of employing a well-known notion (scaffolding) in a less well-known context (multilingual mathematics classrooms), it is essential to study to what extent pupils actually benefit from those scaffolding strategies and, more importantly, *how* they benefit from them. Simultaneously, design research wishes to involve the teacher in trying to understand why and how *pupils'* learning processes develop. In this study, we additionally attempted to promote and study the *teacher's* own learning process. For that reason, we chose to conduct dual design research (Gravemeijer & Van Eerde, 2009), a special case of design research, combining the study of pupil learning and teacher learning.

In this paper we intend to shed light on a mathematics teacher's learning process in dual design research. More specifically, we address the following questions:

1. *What can a teacher participating in dual design research learn in terms of scaffolding pupils' development of the language required for mathematical learning?*
2. *To what characteristics of dual design research can the participating teacher's learning process be attributed?*

2.3 Methods

2.3.1 Setting and pupils

Two teaching experiments were carried out in the last two grades of two suburban primary schools (with pupils of age 10-12 years). In the first teaching experiment, 4 of the 22 pupils spoke Dutch as a second language and at least half of the class could be considered pupils with low language proficiency. After the first cycle, we considered the notion of scaffolding elaborated enough to enact and study in a genuinely multicultural setting. The number of pupils speaking Dutch as a second language in the second teaching experiment was 20 out of 21, the majority being second- and third-generation Moroccan and Turkish pupils, who performed rather weakly on a standardised test for language (CITO assessment). For each teaching experiment, the researchers, in collaboration with the teacher, designed eight lessons in the domain of line graphs, according to the teaching and learning cycle described earlier (Gibbons, 2009). Lessons were given once a week and lasted around 60 minutes.

2.3.2 Participating teacher

The participating teacher, Lara (pseudonym), had 16 years of experience in primary education, partly in multilingual classrooms. At the time of the teaching experiments, she was appointed as an expert mathematics teacher at the primary school she was working at, which included preparing and evaluating mathematics lessons with her colleagues.

Although Lara was to a certain extent already familiar with second language learning issues, she had no experience with scaffolding. Throughout the experiments, Lara showed engagement and a will to learn. She had strong beliefs about good mathematics teaching, but we came to know her as an involved, critical discussion partner, willing to change her view when exposed to convincing arguments.

Lara was not familiar with the pupils in the classrooms she was working in during the teaching experiments; she entered these classrooms as a primary teacher participating in a research project. We presumed that the advantages of working with an expert teacher would outweigh the disadvantages of her being an outsider. For her to become familiar with the situated norms and rules and to get to know the pupils, she observed several lessons beforehand.

2.3.3 Instruments

As we conducted dual design research, the instruments we used to *promote* learning served the pupils or Lara or both.

The first instrument, having a double function, is the hypothetical learning trajectory (HLT; Simon, 1995) for each lesson. It consisted of mathematical and linguistic learning goals, a description of pupils' prior knowledge and assumptions about how the instructional activities and scaffolding strategies would support their learning processes (see Appendix B for an example). In line with the learning activities mentioned in Section 2.4 (experimenting, interaction and reflection), we involved Lara in the formulation of each HLT and reflected with her on how well it matched pupils' learning in the previous lesson. Thus the HLT formed the core of the co-designing process of the teacher and the researchers, providing them with a shared lens through which lessons were designed and evaluated.

The second instrument, used to promote the teacher's learning process, consisted of reflective interviews with the teacher in between lessons, which were increasingly systematised. In the first teaching experiment, after each lesson we had discussions with her, in which different scaffolding-related topics were discussed with no pre-structured order imposed. In the second teaching experiment, we conducted stimulated recall

interviews with the teacher after each lesson, following a set order of question types. For instance, we always started by asking the teacher neutral questions when watching video tapes of the lesson just given, such as: "What happens here? What do you observe when watching this fragment?" The idea behind this approach is to stimulate the teacher to think out loud and thus to stimulate her to relive the lesson (Meijer et al., 2002). In this way, we presumed to promote reflection and thus increase her awareness.

Instruments to *trace* the teacher's learning process included written interview schemes for pre- and postinterviews (Appendix C), used to determine her initial expertise, as well as the development of her scaffolding expertise. A written post-post-interview scheme was used to gain insight into the aspects of her learning environment to which she attributed her learning process.

2.3.4 Data collection

Data collection included audio and video recordings of all lessons, field notes, pupils' pre- and posttest results as well as their written work. We also collected our e-mail correspondence with the teacher. In the second teaching experiment, we asked the teacher to also write reflective reports after each lesson. In this way, we hoped to promote her learning process and gain more insight into her thought processes. Furthermore, two pre-interviews, two post-interviews and one post-post-interview with the teacher were audio-recorded, as were reflective conversations and stimulated recall interviews. All interviews were transcribed (Table 1).

Table 1 Timeline showing dates of interviews and teaching experiments

20 July 2009	Sept. – Nov. 2009	08 Dec. 2009	18 Feb. 2010	March – Apr. 2010	27 Apr. 2010	27 Oct. 2010
First pre-interview	First teaching experiment	First post-interview	Second pre-interview	Second teaching experiment	Second post-interview	Post-post-interview

2.3.5 Data analysis: what did Lara learn?

In the analysis, we initially focused on the first research question: what did the teacher learn in terms of scaffolding language? To find an answer to this question, we have analysed both self-reported and derived learning outcomes. To identify Lara's *reported learning outcomes*, we employed the four main categories from an analytic framework for teachers' reported learning outcomes, introduced by Bakkenes, Vermunt and Wubbels (2010): (1) changes in knowledge and beliefs, (2) intentions for practice, (3) changes in practice and (4) changes in emotions. Bakkenes et al. used this framework to analyse teachers' learning in the context of a national innovation programme across all school subjects and found it a valid and reliable instrument. We used these categories (as

summarised in the descriptions of Table 2) as the main categories in our coding scheme. In Table 2, these categories are shown, as well as examples for each category.

In the transcripts of the first post-interview, the second pre-interview and the second post-interview, all utterances in which Lara explicitly reports on a learning outcome were identified and coded by one researcher. Two independent raters coded a subset of utterances to determine the interrater reliability of the coding process. The $2n^2$ rule (Cicchetti, 1976) was used to determine the number of fragments in this subset. This rule implies that for a reliable interpretation of a computed kappa, the number of fragments should be $2n^2$ or more, where n is the number of codes. Because $n = 4$ in our case, 32 fragments 2×4^2 were used. This resulted in 30 agreements in coding (93.7%; Cohen's kappa = .91), meaning that the four categories could be reliably distinguished.

Table 2 Coding scheme for reported learning outcomes

Code	Description	Examples
ckb	*Change in knowledge/beliefs*: the teacher reports on growing awareness, acquired knowledge, new ideas; or the teacher reports on confirmation of already existing beliefs	I think I am now more aware that these children need to hear new concepts ten times more often than their native peers
cp	*Change in practice*: the teacher states that things have changed in her way of teaching or reports on a change in her way of coaching other primary teachers	Right now I focus more on teaching children how to write in maths lessons
ip	*Intention for practice*: the teacher reports that she wants to do things differently in the future, or reports that the research setting provided her with the insight that she wants to hold on to certain old practices	I really want to be more alert to pupils' precise use of language
ce	*Change in emotions*: the teacher reports on emotions related to the experimental lessons, or reports on being surprised ("unexpected events")	As a result of these lessons, I now feel much more secure when it comes to teaching multilingual pupils

After conducting this analysis, we felt the need to conduct another analysis to gain insight into the *nature* of the reported learning outcomes. Within each category except emotions, we placed all utterances in chronological order. This chronological ordering helped us gain insight into changes over time. However, we also conjectured that the reported learning outcomes only formed the tip of the iceberg. We therefore also *derived* learning outcomes from Lara's statements by comparing utterances in the successive interviews in search of (non-reported) changes. This proved meaningful only for the

category of knowledge and beliefs. We have not found any derived learning outcomes that contradict reported learning outcomes.

As a last step in the analysis of learning outcomes, we categorised all reported and derived learning outcomes representing changes in knowledge and beliefs (105 in total) into five thematic categories: (1) relation between language and thinking mathematically; (2) the writing of a target text in the domain of line graphs; (3) scaffolding language in mathematics education; (4) learning how to scaffold language; (5) pupils' language development and participation.

The first author conducted the analysis, leading to both a summary of changes in practice and intentions for practice, as well as a summary for changes in knowledge and beliefs, specified for each formulated theme. Based on her reading of the thematically and chronologically ordered data, the second author validated these summaries. She judged each conclusion drawn by the first author to be valid. She only suggested two minor reformulations.

2.3.6 Data analysis: to what characteristics of dual design research can Lara's learning process be attributed?

In the pre- and post-interviews we conducted, Lara expressed hardly any statements as to what she attributed her own learning process. When she did, she did so in very general terms, as in the utterance expressed just after finishing the second teaching experiment: "I have thought about mathematics and language for about ten weeks and well, that is quite something. It really makes you think about it all." In a telephone call several months after finishing the second teaching experiment, Lara declared: "This is the first time [in my life] I have actually *really* learned something from professional development." This statement induced us to conduct a post-post-interview so that we could understand her own view on and explanations for her learning.

We decided to split the post-post-interview into a written part, to allow Lara time to think carefully before answering, as well as a verbal part, to allow ourselves to get back to Lara's written answers. In the written part, one of the things we asked Lara was to determine on a five-point scale (1 meaning very unimportant; 5 meaning very important) how she valued different aspects of her learning environment and to explain the attributed ratings. These aspects (18 to be rated in total) included reflecting on instructional activities and relating them to pre-determined lesson goals, feedback on scaffolding strategies, reading and discussing literature, as well as stimulated recall interviews. In the verbal part of the post-post-interview, we asked Lara to further elaborate on some of her answers from the written part of the interview.

2.3.7 Data analysis: illustrating the characteristics of dual design research

In an attempt to identify the aspects of Lara's learning environment (the dual design research setting) that might have enhanced her learning, we focused on the enactment of an exemplary scaffolding strategy, namely the interactive use of an 'expanding word list'. We chose this scaffolding strategy because Lara only managed to perform this strategy in one of the final lessons in the second teaching experiment. We presumed that specific characteristics of dual design research, as carried out in the two teaching experiments, were crucial for Lara's accomplishment. To determine to which of these characteristics Lara's learning can be attributed, we analysed all relevant written data, including reports of reflective discussions, transcripts of stimulated recall interviews and Lara's reflective notes. These findings were supported by triangulating them with our analysis of video fragments, in which Lara enacted the word list scaffolding strategy. These fragments also served to analyse whether and how Lara fine-tuned her use of the word list.

2.4 Results

2.4.1 What did Lara learn with respect to scaffolding language?

Table 3 Distribution of reported learning outcomes among four categories

	First post-interview (post1)	Second pre-interview (pre2)	Second post-interview (post2)
Changes in practice	7	8	12
Intentions for practice	2	6	4
Changes in knowledge and beliefs	11	6	16
Changes in emotions	0	1	1

The majority of reported learning outcomes fell in the category of knowledge and beliefs (33 utterances in total). Changes of practice were reported 27 times; intentions for practice were reported 12 times. Notable is the rarity of changes in emotions: these were only reported twice. We therefore exclude this category from the analysis of changes. Table 3 shows the distribution of utterances among the used categories (changes in practice, intentions for practice, changes in knowledge and beliefs and changes in emotions) for three interviews. For instance, the table shows that the second post-interview contained the highest amount of changes in knowledge and beliefs (16) as well as the highest amount of changes in practice (12). This suggests that it was not until the second teaching experiment that Lara developed a deeper knowledge and a more fluent performance of scaffolding, resulting in a higher amount of reported learning outcomes than reported after the first teaching experiment (interviews post1 and pre2).

In the next subsections, we will present quotes to illuminate Lara's development over time. First, we will do so for reported changes in practice and intentions for practice. Secondly, we will describe the development of changes in knowledge and beliefs, concerning not only the reported learning outcomes as mentioned in Table 3, but also derived learning outcomes (all of these classified into the five thematic categories mentioned before). A summary of these findings is presented in Table 4.

Table 4 Lara's development over time as deducted from reported and derived learning outcomes

	Summary of developments over time
Changes in practice	Lara first became aware of the use of precise, content-specific language by the pupils as well as by herself. Subsequently, she shared this insight with other teachers supervised by her. Later on, she started to stress the importance of the functional and integrated use of language in mathematics lessons.
Intentions for practice	At first, Lara's intentions were only related to formulating more precisely. From the second pre-interview onwards, the variety of intentions increased. Moreover, Lara's intentions also started to include statements on how to develop a teacher's ability to scaffold.
Changes in knowledge and beliefs	Lara developed the belief that language production in general and writing in particular should be more prominent in mathematics lessons. Furthermore, Lara became more aware of: • The difficulty and necessity of adequately performing scaffolding strategies in multilingual classrooms; • Multilingual pupils' hidden linguistic incompetence and the need for them to participate actively and produce content-specific language. Furthermore, Lara's knowledge of scaffolding strategies expanded.

Changes in practice

Below, some utterances containing reported changes in practice are cited. We indicate from which interview these were cited in parentheses.

> I think I ask much more for precise formulations, what the name is of different things… (post1)
>
> I now actually have to formulate grammatically correct myself too. And I do not think I was that alert on formulating in the past. I am getting much more precise now. (post1)
>
> What I always do now when coaching other teachers, while we are…, while jointly preparing their maths lessons, is asking them:
> • Which words does the exercise book use?
> • Do we consider those words useful?
> • Do those words constitute mathematical language?

- Which comparable words do we use in daily language?
- Which words do the pupils already know?
- In which [mathematical] situations do pupils use the words they already know?

So in that sense, I am much more aware of the language to be used. (pre2)

> Only now do I think it is really important that pupils learn to describe a line graph and tell what it stands for and with respect to that I think… I do not think I did that in the past. (post2)

> Look, I did focus on vocabulary in the past [at multilingual schools], but now I think these were actually waffling-on kind of lessons…I am now much more focused on integrating language and mathematics. (post2)

The first two fragments represent Lara's newly gained focus on formulating precisely and correctly (first post-interview). The fragments from the second pre-interview indicate further development. The multifacetedness of the questions she poses to other teachers whom she supervises shows her ability to apply the idea of different modes of discourse and the corresponding types of language. When looking at fragments from the second post-interview, we observe that the reported changes in practice now concern the *functional use* of language in mathematics lessons.

Intentions for practice

When looking at reported intentions for practice, we observe a comparable enrichment. Where Lara's expressions in the first post-interview only focused on paying more attention to formulating precisely, the variety of reported intentions for practice did increase from the second pre-interview onwards. Examples include the intentions: to be more explicit when it comes to using and reinforcing mathematical key concepts; to experiment with different organisation forms aiming at pupils' oral language production; to better integrate language in mathematics lessons. Notable too are Lara's intentions in the second post-interview, as here she started to include intentions of what *conditions* allow her to realise the performance of scaffolding strategies:

> On the other hand, it is needed to also experiment with strategies from which at first I thought 'does this make me happy?' Even if something, like reformulating utterances, was not really my style, I started to see the benefits of this strategy for the pupils. So…so I do need to try things out. (pre2)

> I really want to practise more often [to perform scaffolding strategies], as I do realise that's what I need. (post2)

> I do realise that…I want to more look for ways of implementing scaffolding strategies in other mathematical domains too. (post2)

Changes in knowledge and beliefs

Changes in knowledge and beliefs primarily concerned the theme *relation between language and thinking mathematically*. The most notable change was found in Lara's belief on the significance of mathematical content and language development in mathematics lessons. Before the start of the first experiment, Lara stated that mathematical content should be predominant in mathematics lessons, as is apparent in the utterance "so I think, when talking about graphs, the most important focus should be on what is the graph's *mathematical* structure." After the second teaching experiment, Lara stated: "You always need to talk about language first; only then you can start teaching mathematics." In the same interview she stated:

> I became more aware of that. I mean that language… should not be separated. You actually need language to do mathematics. So we are not going to practise words without context, but when a word appears in a whole-class discussion, *then* we focus on it. You have to integrate it, so that discussing words… eehm, becomes functional.

Within the theme *writing of a target text in the domain of graphs*, we encountered some critical statements. For instance, Lara was initially reluctant to using modelling writing exercises, for instance matching sentences in daily language and mathematical language ('graph language') with segments of the graph, resulting in a target text. Initially, she felt resistance against this approach because of its pre-determined character, which she would normally not allow in her mathematics lessons. Later on, however, she acknowledged the fact that learning mathematics was different from learning (in) a second language and thus different pedagogical approaches were required. As a consequence, she started to adopt a different attitude towards writing in mathematics lessons. We derived changes in beliefs from statements as:

> Yes, I do think writing is very important because it forces you to put your thoughts into words. And that process is actually a matter of understanding. For the domain of line graphs a beautiful scaffold can be constructed for the children [refers to the writing plan that helps pupils to describe each segment of the graph]. So then they can write a text by themselves and it does not matter if that is time-consuming.

An example of a reported growing awareness related to *scaffolding language in mathematics education is*:

> And I notice, when I read [key publications on scaffolding], that I keep thinking 'oh yes, indeed' and then I say to myself: thinking 'oh yes, indeed' actually means that you [I] haven't been performing these scaffolding strategies up to now.

Within the same theme, Lara also reported on changes in beliefs, as in her saying that reformulating pupils' utterances into more academic wordings, although initially not her

style, actually seemed to work really well. For this category, Lara's growing knowledge could mainly be derived from many statements in which she spoke about scaffolding in an increasingly differentiated way. Reflecting upon *learning how to scaffold language*, Lara declared:

> It's like learning a new profession. There are so many optional scaffolding strategies and, well, it is hard to actually choose the right one in a particular situation. You cannot acquire this ability very easily. Yet I do think this is very important. That is why I would argue for professionalising primary teachers on scaffolding.

These utterances support our initial assumption that awareness is interrelated with knowledge, beliefs and intentions: the teacher needs to not only have the intention to scaffold and believe that it works, but also know how to apply which strategy and when. The most notable change in the category *pupils' language development and participation* concerns Lara's view on multilingual pupils' participation in mathematics lessons. This view reveals a growing awareness of pupils' hidden linguistic incompetence. This development can be derived from statements as:

> I have never noticed multilingual pupils to fall off track. (post1)
>
> You need to give these children [multilingual pupils] something extra, because, well, a native-speaking child does *not* need to get exposed to all these words and concepts to be able to participate. (post2)

Another new belief was the conviction that all children – in particular second language learners – should be encouraged to actively participate in mathematics lessons, by producing both oral and written language. This belief is in line with the premise of content-based language instruction that language production is a prerequisite for fully participating in all areas of the curriculum.

2.4.2 To what characteristics of dual design research can Lara's learning process be attributed?

Of all characteristics we asked Lara to rate (on a 1 – 5 scale), there were two aspects which she rated as 3 (the lowest rating she gave): (a) predicting how a particular activity would support a learning goal and (b) writing reflective notes. In the verbal part of the interview, she explained the former as being a matter of difficulty: she considered it difficult to predict pupils' linguistic development. She further explained that writing reflective notes did not specifically add to her learning process, because she already "used to think about these same issues in the past."

Lara did value highly some aspects that were typical for dual design research as enacted in this study (score 4 or 5). In the first place, she mentioned the *feedback* she was given

by the researchers throughout both teaching experiments. Examples included feedback on her increased use of supporting gestures while explaining, as well as feedback related to asking only one question at the time. In the second place, Lara attached great value to the *interventionist character* of the teaching experiments: lesson plans were never written 3 weeks in advance, but often adapted and restructured at the last minute. In her role of *co-designer* – as she stated to have perceived it – Lara appreciated the fact that lessons plans "became her own." She explicitly mentioned the importance of looking back on a given lesson and *reflecting* on the instructional activities. The *stimulated recall interviews* served to observe and analyse in more detail pupils' participation as well as her own role. As she formulated it: "I can see what I do and what I don't do, as well as on what aspects I am focusing and not focusing." Contributing to the *practical elaboration* of different forms of scaffolding made her more aware, Lara said, referring to designed scaffolding strategies that promoted pupils' independence (such as writing plans) as being different from interactional scaffolding strategies (e.g. reformulating pupils' answers or asking them to be more precise linguistically). Finally, she considered the *cyclic character* of great importance. It was only due to revising lessons from the first teaching experiment and enacting them in the second, Lara declared, that she managed to help children reach a higher linguistic level and that she managed to use meta-language (talk *about* language) as an important interactional scaffold. The following paragraph will provide an example that illustrates the benefit of the crucial aspects of dual design research.

2.4.3 An example illustrating the teacher's learning process in dual design research

As an illustration of Lara's learning process we present an example of how she learned to use the 'expanding' word list for subject-specific words as a designed scaffolding strategy. In the lesson plans, all relevant words for each lesson were included and suggestions were made as to which parts of the lesson were suitable for introducing particular words (e.g. axes, increase, gradually). Lara was asked to add these words to the word list when discussing them in whole-class situations. Furthermore, she was asked to refer to these words, either verbally or by pointing at them, once they re-occurred in whole-class discussions. In addition, she was asked to encourage pupils to use the word list as support for speaking and writing mathematically.

Before the third lesson of the *first teaching experiment*, we asked Lara to introduce the word list. However, in the third and fourth lesson, Lara hardly managed to use the word list. We discussed this with her after each lesson, referring to particular lesson episodes that would have been suitable for adding crucial subject-specific words to the list and discussing them. We also encouraged her to combine the word list with the interactional scaffold of asking pupils to be more precise. For instance, for a pupil saying "vertical line", we suggested that Lara ask: "How do we say that in mathematical language?"

Then, 'vertical axis' could be added to the word list. From the fifth lesson on, Lara only occasionally managed to use the word list in whole-class discussions.

In the stimulated recall interviews used in the *second teaching experiment*, we asked Lara to respond to video fragments showing missed and exploited opportunities for word list use. We always started these interviews by posing neutral questions to promote Lara's own reflection. After watching video fragments, we would ask her for instance: "What do you think is happening here?" Increasingly, Lara mentioned the missed opportunities herself. In addition, we provided Lara with feedback on what we observed. For instance, after lesson one, we mentioned that Lara had added words to the word list while pupils were doing group work, hence without pupils noticing the addition of words.

In the first four lessons in the second teaching experiment, Lara again experienced difficulty with using the word list. After lesson two, Lara stated that she just did not manage to add words during discussions, but that she could not explain why. However, after the first few lessons of the second experiment, she repeatedly stated that she agreed with the word list's potential. Only after lesson three did Lara finally point out *why* she could not use the word list as a scaffolding strategy: she struggled with simultaneously promoting mathematical learning and paying attention to the related language. In response to Lara struggling to pay attention to both mathematical learning and language development, one of the researchers explained after lesson three that the development of mathematical concepts and mathematical language are intertwined. Lara seemed very sensitive to this argument and again declared her intention to start using the word list more actively.

She did indeed do so from the fourth lesson of the second teaching experiment onwards. In a report reflecting on lesson four, she wrote that she had repeatedly paid attention to those mathematical words that were already on the list and stated: "I think that most of these concepts have really sunk in now!" After the sixth lesson, Lara declared that mathematical language should not be taught in an isolated way. Although we discussed this issue with Lara earlier, this awareness now seemed a view of her own that she wanted to enact in her teaching. Finally, after lesson seven, Lara stated having mastered the scaffolding strategy of using the word list: "It is now in my system. I don't know why I couldn't do it; it really suits me now."

In sum, the lesson plans were not sufficient support for Lara to actually use the word list as a scaffolding strategy. The dual design research setting, which involved cycles of prediction, feedback and reflection by both the teacher and the researchers, helped her see the need and value of such strategies as well as how to perform them. From the

video analysis, we can infer that her development comprised three phases: (1) writing words when they occurred in classroom discussions, (2) referring to the word list (verbally or by gesturing) and (3) promoting pupils' use of the word list. Towards the end of the second teaching experiment, we observed an increasing number of pupils using the word list as a means of support when reasoning out aloud.

In terms of scaffolding characteristics, these phases signify firstly the *temporal* nature of scaffolding. Secondly, expressing the *intention* to perform the word list scaffolding strategy indeed resulted in its enactment. Thirdly, the *responsive* nature came increasingly to the fore in later lessons. For instance, when pupils were struggling to formulate a graph description, Lara sometimes only needed to point at the word list, which was just enough support for them to produce a mathematically and linguistically correct graph description. This pointing at the word list was repeatedly discussed during stimulated recall interviews.

2.5 Discussion

The present study aimed to shed light on a mathematics teacher's learning process in a dual design research setting. In answer to the first research question, the teacher's reported and derived learning outcomes indicate an increasing awareness of the importance of language development in mathematics lessons, an increasing frequency and variety of intentions to scaffold language and a growing awareness of the linguistic struggles of multilingual pupils, hence the necessity to perform scaffolding strategies. Increasing knowledge of scaffolding language was derived from statements throughout the interviews.

In answer to the second research question, the teacher attributed her learning to many characteristics of how we shaped dual design research: the cyclic and interventionist character, her co-designer's role, the stimulated recall interviews that promoted reflection and the feedback she received from the researchers. In terms of the learning activities (Sect. 2.4), she particularly valued experimenting, interaction with the researchers and reflection. The overall conclusion from the analysis is that the dual design research setting promoted the development of the teacher's knowledge and beliefs with regard to scaffolding, but also fostered changes in practice and intentions for practice.

In summary, we argue that dual design research is a valuable way of developing particular innovative expertise. Once there is a solid empirical and theoretical basis on a topic, other, more efficient ways to develop this expertise at larger scales should be deployed. In the remainder of this section, we therefore discuss how our findings could be

"generalised' to professional development at a larger scale. To this end, we first need to raise two points.

The first point is that statistical generalisation is not possible here. As in other types of qualitative research, design research aims to gain insights into *mechanisms*, acknowledging their dependence upon the social and cultural contexts in which these mechanisms operate (Maxwell, 2004). Using an example of Lara's learning, we mention the underlying mechanisms that we think can be drawn on in subsequent cycles of dual design research (analytic generalisation).

Lara repeatedly stated experiencing a field of tension between mathematics and language. We observed her struggling with finding a way to use language functionally and to perform scaffolding. For example, only in one of the later lessons of the second teaching experiment did she express the view that key concepts should be discussed *while* dealing with mathematical content and thus not be explained in a vocabulary-teaching way. Lara at that time seemed to have developed the awareness that two *foci* (Mason, 1998) are needed to realise scaffolding: attention to mathematics and attention to language simultaneously. Mason's claim that awareness is a prerequisite for learning is substantiated by the fact that Lara soon after did indeed finally manage to functionally – and naturally – use the word list in her lessons. The mechanisms underlying this growing awareness are presumably first that Lara was constantly challenged to reflect on her actions, to make her thinking-in-action explicit and to formulate how instructional activities and scaffolding strategies would support pupils' learning processes. Second, the stimulated recall interviews provided her with feedback, making her aware of "blind spots" in her teaching.

The second point we need to make is that our dual design research has yielded not only knowledge of Lara's learning process, but also theory and instructional activities on scaffolding language in mathematics education, in the form of a conceptual framework of scaffolding strategies, empirically tested prototypical lessons and video footage and transcripts of how different strategies can be enacted. A new teacher could therefore draw on resources that we did not yet have available when starting to work with Lara.

These two points help to sketch a route towards upscaling scaffolding expertise among larger groups of teachers. We have already taken the first step of this route: in a next teaching experiment, we worked with another teacher with less teaching experience than Lara and with no prior knowledge of scaffolding. Some characteristics of our dual design research setting, such as stimulated recall interviews, were maintained, but we did not involve her in co-design for efficiency reasons. Yet the new teacher learned to perform scaffolding

strategies at least as fast as Lara. We explain this by referring to the two aforementioned points. In this next teaching experiment, we could build on the resources coming out of the first dual design research cycles such as the resulting framework of scaffolding strategies and concrete examples. Furthermore, our insights into the mechanisms that promoted Lara's learning helped us support the new teacher more efficiently.

The second step is to use the products and insights from our research in a 'next' level of dual design research: a professional development course is designed in collaboration with a teacher educator (or Lara) to promote mathematics teachers' scaffolding expertise. Because of the innovative nature of this next level of dual design research, we envision that intensive methods such as co-design are necessary. This first dual design research cycle would yield both knowledge of the teachers' learning and the means to support that learning and the teacher educator's learning necessary to facilitate that learning. Again, a second cycle would be less labour intensive and a "train the trainer" model can be used for further scaling up the development of teachers' expertise.

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Chapter 3

Development of a pedagogical genre and evaluation of pupils' genre proficiency: A linguistic turn in educational design?

This chapter has been submitted as:
Smit, J., Van Eerde, H. A. A., Kuijpers, M., & Bakker, A. (2013). *Development of a pedagogical genre and evaluation of pupils' genre proficiency: A linguistic turn in educational design*?

Abstract

Given the important role of language in learning, we argue that design researchers need to think through the consequences for designing for, in our case, mathematics education. Drawing on genre pedagogy and a design-based research project on reasoning about line graphs, we introduce the notion of pedagogical genre, which is a genre that has been deliberately designed as a learning goal. It is captured in terms of structure and linguistic features with examples as an instructional aid for teachers to focus their and pupils' attention on what matters most in talking or writing about a particular domain. The aims of this paper are to summarise the development of the pedagogical genre and to evaluate pupil proficiency in the pedagogical genre. The evaluation took place in a teaching experiment of nine lessons involving 22 pupils (aged 10-12, grades 5-6); 19 had Dutch as their second language. On the basis of pre- and posttest results and the analysis of interviews with four case-study pupils, we conclude that their proficiency increased statistically significantly and with very large effect size (d = 2.20).

Keywords

Design-based research · genre pedagogy · line graph · mathematical language · second-language learners

Development of a pedagogical genre and evaluation of pupils' genre proficiency: A linguistic turn in educational design?

3.1 Introduction

Over the last decades, educational researchers have increasingly stressed the important role of language in education. This role is reflected in the frequent use of notions such as literacy, discourse and dialogue. Although these notions have different meanings in different theoretical frameworks (Chapman, 2003), they commonly point to what we can call a linguistic turn in educational research. What emerged from the study that we report on here is that the consequences of such a linguistic turn, however, need to be thought through more radically and thoroughly when it comes to educational *design*. Design research typically focuses on both development of materials and understanding how learning processes evoked by such innovative forms of education actually take place (e.g., Gravemeijer & Cobb, 2006). In educational design for content-based subjects, however, language has predominantly played an epiphenomenal role. In this article we present one way in which a linguistic turn could be elaborated.

Attention for language in educational design is especially important in the case of multilingual classrooms. Worldwide, numbers of pupils with a migrant background are increasing, as a consequence of which teachers face the challenge of teaching in classrooms where many pupils participate through a language of instruction that is not their first language (Elbers, 2010). International achievement studies show that this challenge is not sufficiently met. The Programme for International Student Assessment (PISA), for instance, has revealed that in many countries immigrant pupils perform significantly worse on literacy and mathematics than their native peers (Gille, Loijens, Noijons, & Zwitser, 2010; OECD, 2003, 2004; Schleicher, 2006). Such studies urge researchers to carry out interventionist research that centralises language proficiency in different areas of the curriculum and that orients teachers toward supporting pupils' language learning. More specifically, an explicit focus on domain-specific language that provides access to particular types of discourse has been advocated (e.g., Gibbons, 2002). For instance, Halliday (1978) argued that learning mathematics implies learning to use language for mathematical purposes. More specifically, scholars have pointed to the variety of forms and patterns language takes in different mathematical domains (e.g., Moschkovich, 2010; Schleppegrell, 2010). Moschkovich, however, noted that interventionist research focusing on language development for mathematical learning is scarce. The aim of the study reported here was to design, enact and evaluate language-oriented mathematics education (cf. Van Eerde & Hajer, 2009). Although native[1] pupils

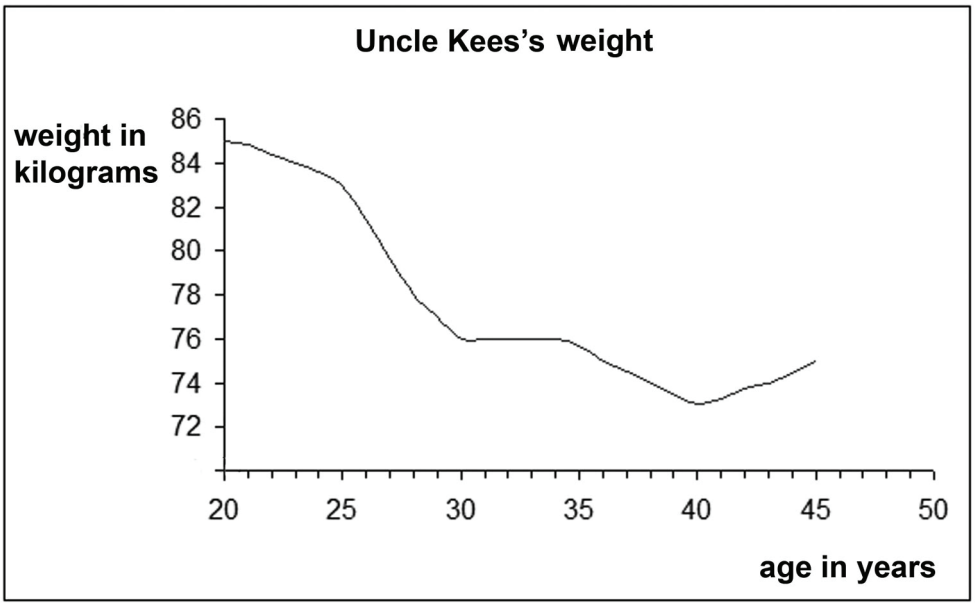
have also been assumed to benefit from such an approach, such explicit focus on language forms the gateway to better educational and societal opportunities for immigrant pupils (e.g., Adler, 2001; Campbell, Adams, & Davis, 2007; Schleppegrell, 2007).

Our approach to language-oriented mathematics education was especially informed by genre pedagogy (Martin, 1989), also referred to as an "explicit pedagogy for inclusion and access" (Cope & Kalantzis, 1993, p. 64). The notion of genre is typically associated with particular literary forms of writing, for example a poem, a novel or a scientific article. Genres have particular linguistic and structure features. The language used in poems has different features than that in a novel or an article, but these genres also have different structures than poems. In genre pedagogy, scholars have distinguished six key genres for learning in the school context: recount, narrative, discussion (or argument), procedure (or instruction), report, and explanation (e.g., Derewianka, 1990; Martin, 1989). These genres involve ways of communicating needed throughout the curriculum, but also in society, where they serve particular societal purposes that are reflected in the way texts are structured as staged goal-oriented processes. The core idea of genre pedagogy is to pay explicit attention to linguistic and structure features of genres in order to provide pupils with access to the official discourses of the classroom (Hyland, 2004; Morgan, 2007).

So far, genres have been analyzed as phenomena already existing in society and schooling. We have found no literature on how they evolve, let alone how teachers or researchers can deliberately mould them. In our research project, however, we felt the need to design a means of supporting pupils' reasoning about line graphs. In response to this need we have come up with the idea of a *pedagogical genre*, a staged, goal-oriented text type that has been deliberately designed for pedagogical purposes, both as a linguistic learning goal and a means to support pupils' talking and writing in a particular domain. A set of structure and linguistic features with examples forms an instructional aid for the teacher to focus her attention and that of the pupils on what matters most in talking or writing about the particular domain. Where the concept of genre refers to socially recognized ways of using language in and outside of school (Spycher, 2007), pedagogical genres are to be established more locally in classrooms and may as such include conventions not commonly shared out of school. They can have a temporary and transitional nature as preparation to more conventional genres.

To give an impression of what we mean by a pedagogical genre, we refer to an exemplary text from the pedagogical genre we designed for reasoning about line graphs; see Figure 1. A pedagogical genre has particular linguistic features that are necessary for –

in this case – reasoning about line graphs, for example that it should distinguish between gradations of steepness (as in "the graph descends *gradually*"). Furthermore, it has particular structure features, here related to conventions to be established in the classroom. For example, pupils are expected to identify parts of the graph and underpin each interpretation (e.g., "his weight decreases quickly") with a description related to the course of the graph ("you can tell as the graph shows a steep fall"). What we designed is of course not the language used, but the structure (e.g., stages) of pupils' reasoning about the graphs and some of the linguistic features to which teachers should pay attention. To test whether it is feasible for fifth- and sixth-grade pupils to become proficient in such a pedagogical genre, we also evaluated the progress in their genre proficiency. The aims of this paper are to summarise the development of this pedagogical genre and to evaluate what pupils learned from our approach that focused on promoting pupil proficiency in the pedagogical genre.



At the age of 20 Uncle Kees weighs 85 kilograms. Between his 20th and his 25th birthday, he slowly loses weight. The graph descends gradually. Between his 25th and his 30th birthday his weight decreases quickly. You can tell as the graph shows a steep fall. From his 30th to his 35th birthday his weight remains more or less the same. The graph is constant. Between his 35th and his 40th birthday he slowly loses weight; the graph gradually descends. When Uncle Kees is 40 his weight reaches its minimum: about 74 kilograms. From the age of 40 on his weight increases slightly. In this part, the graph gradually rises.

Figure 1 Line graph and exemplary text from the pedagogical genre that we call *interpretative description of a line graph*

3.2 Theoretical background

3.2.1 A linguistic turn in education

The term linguistic turn has been used to denote a shift from a focus on discipline-bound content (with language being epiphenomenal) to explicit attention to the structure and usage of language in a particular discipline, as well as to the relation between language and human thinking. Such a shift can be traced in several disciplines in the humanities and social sciences. As one of the progenitors of the linguistic turn, Wittgenstein (1953/2001) proposed the idea that philosophical problems arise from a misunderstanding of the logic of language. In Rorty's influential book *The Linguistic Turn* (1967), the term refers to the move toward philosophy of language.

In education, many scholars have been influenced by this linguistic turn. This tendency has been accompanied by an increasing focus on participationist learning (Chapman, 2003). Opposite to acquisitionist or transmission-oriented scholars, scholars adhering to a participationist view on learning regard human intellectual growth as resulting from participation in social interaction. The underlying idea is Vygotsky's (1962) claim that higher mental functions are constituted by social processes, rather than by biological capacities of an individual. The role of language as a mediating tool is key to such social processes. Building on Wittgenstein and Vygotsky's work, Sfard (2008) elaborated the idea that thinking is a form of communicating. Elaborating this idea for mathematics, she argued that "attending to words and thought separately is like trying to find out properties of water by looking at those of hydrogen and oxygen" (Sfard, 2001, pp. 21-22). Some scholars indeed go so far to claim that mathematics is a language (e.g., Mousley & Marks, 1991), suggesting that if pupils talk the language of a particular school subject, they have access to its content. Others view language as one of many semiotic systems operating in mathematics (Schleppegrell, 2007), or as a scientific tool to access scientific (mathematical) content (cf. Janzen, 2008). The point we want to address, however, is not that there is a variety of approaches mirroring contradictory understandings of mathematics and language (cf. Chapman, 2003), but that there is a widespread consensus on language playing a vital role in scientific, or more specifically, mathematical learning. This comes to the fore in well-known book titles such as *Speaking Mathematically* (Pimm, 1987), *Talking Science* (Lemke, 1990), *Discourses in Mathematics* (Mousley & Marks, 1991), *Talking Mathematics in School* (Lampert & Blunk, 1998), and *Language Practices in School Mathematics* (Chapman, 2003).

3.2.2 Realising a linguistic turn in education: genre pedagogy

Realising a linguistic turn in educational design implies the deployment of an approach that explicitly attends to how language is structured and used in particular areas of the curriculum. The approach that has most explicitly and successfully focused on types of

language that pupils need for participating throughout the curriculum and in society is genre pedagogy (as noted by Johns, 2011). We briefly sketch the history of genre pedagogy, definitions of genre that have been prominent within educational research, and subsequently revisit the most common classification of genres for purposes of schooling.

For about two decades the notion of genre and its application in education have been the focus of innovative research on language teaching and learning (Hyland, 2007). Different camps vary in the extent to which they focus on theory or on practice of education (Yasuda, 2011). Where theory-oriented scholars mainly examine *genre awareness* and the broader context in which genres occur, pedagogy-oriented genre approaches focus on deliberately supporting pupils' *genre proficiency*, thus on the teaching and learning of specific text types considered to be "common exemplars of genres" (Johns, 2011, p. 57). Both camps view genres as already existing in society, but the latter movement attempts to educationalise these existing genres by focusing on their social purpose in relation to text structure. One of these text-driven pedagogies, known as the Sydney School (Cope & Kalantzis, 1993), has been most prominent in primary and secondary multilingual classrooms both inside and outside Australia. Although we acknowledge that other genre approaches may also offer valuable perspectives on language teaching and learning, we adhered to this Sydney School genre approach. This approach seemed the most suitable for our overall purpose of designing language-oriented mathematics education, as it offers the most concrete tools and insights for supporting language proficiency in the context of school.

Concerning definitions of genres, we make two observations. First, there is a large variety of genre definitions, even amongst scholars within the Sydney School (cf. Cope & Kalantzis, 1993). Second, genre definitions vary from more descriptive and analytic, to definitions formulated with an eye on the practice of education. An analytic definition stems from Spycher (2007), who defined genres as "socially recognised ways of using language that enable people to say things about the world, establish relationships, and accomplish tasks" (pp. 240-241). Martin and Rose (2008) stated that genres are recurrent configurations of meaning and that these recurrent configurations of meaning enact the social practices of a given culture (p. 6). Both analytic definitions have a strong societal connection, but do not provide concrete tools for centralising genres in education.

Educationally embedded genre definitions include aspects of the structure and linguistic features that compose them. For educational linguistic work with teachers, Martin (2009), for instance, redefined the notion of genre as a "staged goal-oriented social process" (p. 13). The term staged refers to how meanings in text types are phased through stages in reasonably predictable ways, represented in a schematic structure. A

written report, for example, usually starts with an opening statement, general classification or definition, followed by facts about various aspects of the subject (Derewianka, 1990). The underlying idea is that a social purpose to be achieved requires moving in steps, so that by the end of a text the purpose has been fulfilled. An even stronger relation to educational practice form genre definitions that explain genres as types of texts that work in a particular way to get things done in a particular culture. Several scholars have drawn attention to the whys and the hows underlying particular text conventions (Cope & Kalantzis, 1993; Chapman, 2003). Mousley and Marks (1991) noted: "Genre refers to the 'shape' of language use, in that we use traditional patterns of language for specific purposes" (p. 17). Barring differences in defining the notion of genre, we note that genre scholars oriented toward education share the assumption that text types for schooling and the conventional patterns present in these text types need to be taught and learned explicitly.

Several scholars have proposed classifications of key genres required across the curriculum which also occur in the world outside school. The six key genres (report, explanation, procedure, discussion, recount and narrative) have most often been considered central to genre teaching. As they have different social purposes, they bring along different conventions in terms of schematic structure and linguistic features, and these can be taught explicitly to pupils. In different curriculum areas, scholars have investigated whether and how these genres operate (e.g., Mousley & Marks, 1991, for mathematics). However, several researchers have identified more specific genres for schooling. Christie (1993, p. 159), for instance, described "the morning news genre." This genre requires pupils' linguistic capacity to use language for the representation of an experience, and is distinctive in the particular phases involved (e.g., opening, morning news giving, closure). Gerofsky (2004) analysed mathematical word problems as a genre with a long history that does not fall under one of the six key genres. Such examples underpin our view that the six key genres do not suffice to cover all genres needed for schooling. Moschkovich (2010) argued that there are domain-specific mathematical genres that need to be examined to get a clearer picture of what constitutes linguistic competency for mathematics. The range of such genres may well be boundless (Mousley & Marks, 1991). We now discuss the mathematical domain that was central to our study (line graphs) and describe the considerations that led to developing a pedagogical genre for this domain.

3.2.3 Deploying genre pedagogy for the domain of line graphs

In our aim to design, enact and evaluate language-oriented mathematics education, we decided to focus on line graphs for several reasons. In the first place, the domain of line graphs is linguistically more challenging than domains to which arithmetic or algebra is

central (Moschkovich, 1996). The language needed involves not so much procedures and the use of technical terms, but rather precise descriptions with an underlying conceptual understanding. Roth and Bowen (2003) characterised the complex nature of the domain as follows. On the one hand, line graphs are topological in that lines represent the continuous change of real-world phenomena. Language, on the other hand, is typological since it divides the world into "objects and classes of objects" (p. 430). Thus, when reasoning about line graphs, these two features meet, which makes the genre different from non-mathematical genres. Furthermore, pupils have been found to experience many difficulties in the domain of line graphs (cf. Leinhardt, Zaslavsky, & Stein, 1990). For instance, pupils have difficulty expressing and interpreting change in line graphs. Lastly, as graphs are not only fundamental in mathematics but also indispensable in the fields of physical and social sciences (Nathan & Kim, 2007), it is vital to address the difficulties and challenges belonging to the domain.

Mathematical domains with a long history in teaching and learning often dispose of agreed-upon forms of speaking and writing that are particular to the context of school. One example is the school-based genre of early arithmetic. No one outside school would say *five take away two*, but this is common language in early arithmetic classrooms (at least in our country), as preparation for the culturally better known and more sophisticated *five minus two*. Also mathematical word problems draw on a long history concerning its genre characteristics (Gerofsky, 2004; Van Maanen, 2001). Unlike domains as arithmetic or mathematical word problems, line graphs are a relatively recent phenomenon in history (Bakker, 2004; Beniger & Robyn, 1978), and thus also in education. Moreover, compared to arithmetic and word problems, their introduction in primary school levels is more recent. This may explain why for the teaching and learning in this domain recurring ways of speaking and writing are much less specified – and perhaps more variable.

Due to the language in the domain of line graphs being less conventionalised and specified than in other mathematical domains, we wanted to explore the idea of designing a genre for this domain ourselves. This pedagogical genre should help pupils overcome difficulties that pupils typically have (e.g., reasoning about change). As such, it would include features that are directly related to the domain (cf. Moschkovich, 2010). The term "design" may sound counterintuitive in this context: Any genre deploys existing pedagogical and content registers (Christie, 1993) and other semiotic resources (e.g., graphical representations). However, not only artefacts but also pupil activity can be designed (i.e., structured). What we designed were structure and linguistic features with examples that function as a means of supporting pupils' reasoning about line graphs, including the stages that pupils are expected to go through in describing graphs.

In the following section, we summarise how we employed design research, which theories we used, and how our design challenges led to the development of the notion of pedagogical genre.

3.3 Designing language-oriented mathematics education

3.3.1 Design research

In this section we argue that design research suited our purpose of designing language-oriented mathematics education well. In the first place, design research prototypically entails the "engineering" (Freudenthal, 1991) of forms of learning that do not yet exist. In contrast with forms of learning that can be studied naturalistically, design research thus has a highly interventionist nature. At the core of this process lies the following adage: "If you want to understand something you have to change it and if you want to change something you have to understand it" (Bakker, 2004, p. 37).

In the second place and as a consequence of the engineering nature, design research has a cyclic character: The development of innovative types of education involves cycles of prediction and invention, followed by a teaching experiment, followed by reflection and revision. Unlike research approaches in which teaching experiments serve to test preconceived designs, design research is distinctive in its (sometimes overlapping) iterations of anticipation, enactment and evaluation (Gravemeijer & Van Eerde, 2009).

In the third place, design research has the potential to generate particular types of theory that can help to shape interventions (diSessa & Cobb, 2004). Typically, cycles of design research generate innovative and empirically grounded domain-specific instructional theory. In this research, however, the theoretical intent is not only to develop insights into teaching and learning about a specific domain (line graphs) and the means to support such domain-specific teaching and learning, but also to develop, implement and evaluate an innovative approach in the spirit of a linguistic turn in educational design. At the outset, it was not clear to us what exactly we would need to design in order to enact language-oriented mathematics education for the domain of line graphs. We trusted the experience of design researchers that theory could emerge from practice and feed back to guide it (e.g., Gravemeijer, 1994). Space does not allow us to provide the chronological details of this process. Therefore we do not summarise the development of the concept over the three cycles, but present a theoretical and empirical justification of how we came to mould a pedagogical genre for reasoning about line graphs by defining linguistic and structure features with accompanying text examples.

3.3.2 Theories involved in this study

We drew on several types of theories, which we in diSessa and Cobb's (2004) terminology call orienting frameworks and frameworks for action. The *orienting framework* is sociocultural theory, primarily informed by Vygotsky's (1962, 1978) ideas. Three of these are particularly relevant within our study. First, Vygotsky's developmental theory stressed the role of joint activity (e.g., social interaction) in the construction of knowledge. Second, language is seen as a mediating tool with two main functions: as a communicative or cultural tool, used for the collaborative construction and sharing of knowledge; and as a psychological tool, used for individual thought and reflection. Third, in social interaction, the parent (or teacher) can fulfil the role of "more knowledgeable other" (expert), who could lead children (novices) on to new skills or levels of conceptual understanding. Closely related to this notion of more knowledgeable other is Vygotsky's (1978) concept of *zone of proximal development* (ZPD). Although interpreted in various ways (cf. Chaiklin, 2003), the concept of ZPD has most often been used to refer to a space where learning takes place (Litowitz, 1993), under the guidance of an expert.

Vygotsky's core ideas of both thinking as an individualised version of social interaction (cf. Sfard, 2008) and of dialogue between experts and novices being crucial for cognitive development have increasingly led to classroom talk as a focus of educational studies (e.g., Cazden, 2001). The elaboration and application of new concepts and frameworks were the result. An example is the concept of scaffolding (Wood, Bruner, & Ross, 1976), mostly described as temporary and responsive help that is provided by a teacher to help a pupil move forward in the ZPD – aiming at the pupil's independence. Scaffolding functioned as the key concept in our orienting framework: It provided us with a perspective on which we based our empirically grounded conceptualisation of *whole-class* scaffolding (Smit, Van Eerde, & Bakker, in press; see also Chapter 4 in this thesis), and it generally informed the construction of a repertoire of interactive strategies to be enacted by the teacher to support multilingual pupils' language learning in whole-class settings (Smit & Van Eerde, in press; see also Chapter 5 in this thesis). The concept of scaffolding, however, did not directly relate to decisions of design.

The *frameworks for action* in our study were genre pedagogy and the theory of realistic mathematics education (RME; Freudenthal, 1991). From genre pedagogy we particularly deployed the *teaching and learning cycle*, also referred to as the teaching-learning cycle or the curriculum cycle (e.g., Derewianka, 1990; Gibbons, 2002; Rothery, 1996). The purpose of the teaching and learning cycle is to induct pupils in written-like, academic genres needed for participating throughout the curriculum. Gibbons (2009) characterised such genres as less personal, more abstract, more explicit, more lexically dense and also more

structured than the daily language with which pupils are familiar. The teaching and learning cycle, employed as a design heuristic, consists of four phases through which a particular genre can be made explicit to pupils. Each of the phases has a specific teaching purpose (Gibbons, 2009) and informs the planning of classroom activities related to different teacher-learner roles (Hyland, 2007). In the first phase, known as *building the field*, pupils and teachers explore the context in which a genre is to be used to build up common basic understandings. In the second phase, known as the *modelling* phase, purpose, structure and features of the genre are explored by means of sample texts or modelling activities (e.g., writing activities by use of writing frames in which parts of sentences are left out). During the third phase of *joint construction* a teacher scribes a text in the genre based on suggestions from pupils. In this joint construction of text, the teacher plays a crucial role in bridging discourses (Gibbons, 2006). That is, in classroom interaction the teacher is to scaffold pupils' language from more spoken-like to more written-like. The fourth phase of the teaching and learning cycle is *independent writing*, in which pupils are expected to draw on their learning in the previous three phases and to write in the genre without support by either the teacher or models. This independence is the final stage of gradually withdrawn support and direct instruction.

As a complementary framework for action we used the more domain-specific theory of RME. It was developed in the Netherlands in the 1970s and has been used and extended in both the Dutch context and in other countries ever since. Underlying the theory of RME have always been Freudenthal's idea of mathematics as a human activity that should be meaningful to pupils, and his goal of "mathematics for all" (Freudenthal, 1991, p. 178; Van den Heuvel-Panhuizen, 2012). This latter idea fits well with the principle of inclusion and access underlying genre pedagogy. Where Freudenthal aimed to provide pupils at all intellectual levels with access to mathematics, genre scholars aim to provide pupils with culturally and linguistically diverse backgrounds better educational opportunities throughout the curriculum.

Several RME tenets and principles informed the design of our lessons concerning the mathematical goals, but not our linguistic goals. We aimed to promote a process of *progressive mathematisation* (Treffers, 1987): the development from intuitive, informal, context-bound notions toward more formal mathematics, with the support of symbols and models (in our case a line graph). Meaningful situations were to form the starting point for this process (in our case, for instance, the growth of a sunflower over time), and these situations were first phenomenologically explored by pupils. To allow for progressive mathematisation, we designed lessons in the spirit of *guided reinvention*. This principle refers to particular guidance that pupils receive in the process of reinventing the mathematics that was invented in the past (Gravemeijer, 1994). The instructional design, on one hand,

guided the reinvention of the line graph model, for example by including open mathematical problems that enhanced pupils' progress toward more formal mathematical activity. The teacher, on the other hand, was guider of this reinvention process by asking pupils guiding questions, promoting negotiation of meaning and by trying to make sure that the pupils would experience their learning as a process of inventing mathematics (cf. Gravemeijer, 2008). In this process, pupils' *own productions* were promoted as an essential part of this process (e.g., pupils' own representations of the growth of a sunflower). In discussing pupils' own contributions and mathematical subject matter, pupils' *interactive participation* was encouraged. Although the tenets and principles of RME seemed very compatible with the idea of a linguistic turn in designing mathematics education (Van Eerde & Hajer, 2009), they did not directly inform us on how particular aspects of subject-specific language could be designed.

A valuable research instrument in connecting various types of theories with practical experience is the *hypothetical learning trajectory* (HLT; Simon, 1995). It consists of (a) an overall learning goal, (b) pupils' anticipated starting point, (c) instructional activities (typically for one lesson) and (d) assumptions about how the instructional activities would support mental activities that lead to the overall learning goal. Its primary function is to formulate hypothetical learning in the design phase of design research. During the enactment of instructional activities in the classroom an HLT can direct the teacher and researcher's attention. Because the HLT is focused on pupil learning, we complemented it with a teacher guide to assist the teacher. In retrospect, the HLT can be used to analyse pupils' participation and learning. In our design research project, an HLT was formulated for each lesson. Each HLT was based on an anticipatory thought experiment by both the researchers and the teacher (cf. Cobb, McClain, & Gravemeijer, 2003) in which they attempted to envision how the instructional activities could be realised in the classroom, and what pupils would learn by participating in these activities. When designing HLTs, we encountered a gap between genre pedagogy as a framework for action and the concrete case of interpreting line graphs: For designing aspects of language use needed for reasoning about line graphs, the aforementioned six key genres proved too unspecific and too content-transcending. The idea of a pedagogical genre emerged, which assisted in our design process and thus helped to manage the gap.

As formulated in the introductory section, the aims of this article are to summarise the development of a pedagogical genre and to evaluate what pupils learned from our approach that focused on pupils' proficiency in this pedagogical genre. In the following section, we summarise the development of the pedagogical genre needed for reasoning about line graphs. This summary further forms the response to the challenge of managing the gap.

3.4 Development of a pedagogical genre

Three teaching experiments were carried out in the last two grades (age 10-12) of three different suburban and multilingual primary schools (respectively 6, 8 and 9 lessons). Second language learners were generally second and third generation Moroccan and Turkish pupils.

For each teaching experiment the researchers, in collaboration with a teacher, designed lessons in the domain of line graphs. This teacher was not employed at any of the three schools involved in the research project. We asked her to participate in the teaching experiments, because she had 17 years of experience in primary education, partly in multilingual classrooms. Moreover, she was an expert in the field of RME, which we considered a prerequisite for enacting language-oriented mathematics education as envisioned in our study. In the following, we will refer to the participating teacher as "teacher" and to the regular teacher of the primary class involved in the third teaching experiment as "class teacher."

3.4.1 Requirements derived from the literature

We decided to conduct a literature review to derive requirements for the design of a pedagogical genre to reason about line graphs. These requirements led to the initial formulation of structure and linguistic features of the pedagogical genre. The experimental phases of our design research cycles informed the further development of the pedagogical genre features. This development is summarised in the next section.

In deriving general requirements for the pedagogical genre to be developed for reasoning about line graphs, we first investigated what different types of language are involved in mathematical learning more generally. Second, we studied the nature of the domain of line graphs and their function in mathematics education. Third, we searched for descriptions of difficulties that pupils have with reasoning about line graphs. In the following, we present and motivate the three requirements that formed the yield of these investigations of relevant literature.

> *Requirement 1*: The pedagogical genre should deploy everyday language, general academic language and subject-specific mathematical language

There are different categorisations in types of language required for subject-specific mathematical learning. The most common distinction is between *everyday* and *academic* discourses, or similar labels (e.g., Gutiérrez, Sengupta-Irving, & Dieckmann, 2010; Sfard, 2001). For multilingual classrooms it can be useful to view language learning as a three-dimensional process (Setati & Adler, 2000). More specifically, this implies that academic language is further subdivided into *general academic* language and *subject-specific*

language. The former refers to the language related to learning at school, but that is not content-specific. The latter refers to language related to a particular subject (in our case mathematics). Being familiar with general academic language (e.g., words such as *increase*, *equal*, *growth* and *process*) has been argued to support the development of subject-specific mathematical language (Ferrari, 2004; Moschkovich, 2002). Native speakers tend to develop general academic language as a by-product of classroom participation, implying that for them this type of language typically does not need explicit attention. However, for second language learners this is mostly not the case (e.g., Gibbons, 2002). Thus, in multilingual classrooms it seems crucial to focus on general academic language learning to allow for the development of subject-specific mathematical language.

Several scholars have argued against categorical distinctions (e.g., Forman, 1996). Gibbons (2002) prefers to think of a mode continuum. Setati, Adler, Reed and Bapoo (2002) described possible "journeys" (p. 136) from informal spoken language to formal written language in multilingual mathematics classrooms. However, in line with Gutiérrez et al. (2010), we feel that there are good reasons to contrast types of language for educational purposes, as it helps to make both pupils and teachers aware of specific linguistic competencies that need to be developed for participation in particular domains. Thus, we aimed to scaffold pupils' everyday language (e.g., *gets more and more*) toward more general academic language (e.g., *increase*) as a basis for the development of subject-specific mathematical language (e.g., *steepness*) at the end of the mode continuum. In formulating Requirement 1 we do not want to suggest strict boundaries between different types of language.

> *Requirement 2*: The pedagogical genre should help pupils to interpret natural phenomena that graphs represent but also to describe the graphs themselves

Line graphs, at least at the primary level, typically represent data of real-world phenomena (e.g., weight or growth). Leinhardt et al. (1990) consider graphs "communicative systems, on the one hand, and a construction and organisation of mathematical ideas on the other" (p. 3). In the same review, they stated that graphs could have a bridging function between reasoning from the concrete to the abstract. Monk (2003) also pointed toward such a distinction between the abstract and the concrete in his observation that pupils can build understanding of the graph and its context simultaneously by exploring both: "A graph can be used both as a window into a phenomenon and as a world of meanings in its own right" (p. 256). The pedagogical genre that is to provide access to reasoning in the domain of line graphs should in our view express such relations between the natural phenomena represented and the mathematical phenomena.

> *Requirement 3*: The pedagogical genre should assist pupils in relative (here: across-time) reading of graphs in relation to the natural phenomena the graphs represent

Leinhardt et al. (1990) distinguished between pointwise reading of graphs and relative (across-time) reading and interpretation. We use Figure 1 to illustrate related difficulties. A question that elicits pointwise reading is "how much does Uncle Kees weigh when he is 35 years old?" A question that elicits across-time reading is: "What happens to Uncle Kees's weight between his 30th and his 35th birthday?" Leinhardt et al. revealed that pupils tend to maintain focus on individual points in the graph, even if these points are connected with a line: "…although lines are accepted as a legitimate part of graphs, they seem to serve a connecting function rather than possessing a meaning in their own right" (p. 34). Similarly, Monk (2003) stated that pupils found across-time questions far more difficult to answer than pointwise questions. Another difficulty includes pupils' tendency to regard graphs as entities that embody causalities (Leinhardt et al., 1990): for example, "Uncle Kees became heavier because he ate too much." What is also relevant to across-time reading of graphs is pupils' difficulty with understanding constant functions, as pupils tend to only view changing quantities as legitimate. Interpreting gradations of a graph's steepness has also been addressed as challenging for pupils (cf. Shah & Hoeffner, 2002). Taking these difficulties together, we concluded that we should explicitly focus on the links between visual features (e.g., gradual increase) and their meaning. This led to the third requirement. We focused on qualitative graph features as preparation for more advanced quantitative reasoning about line graphs in secondary education (cf. Dekker, 1991).

3.4.2 Design of the pedagogical genre for reasoning about line graphs

The three general requirements formed the first source that informed the design of specific structure and linguistic features of the pedagogical genre that we called *interpretative description of a line graph* (see Figure 1). These features intended to provide teachers with conventions to be established in the classroom and pupils with tools for reasoning about line graphs. In three cycles of design research, different sources (e.g., an expert questioning round and the empirical data) further informed the design of structure and linguistic features of the pedagogical genre (see Table 1 for the resulting features). In Table 1, a "segment" of a graph refers to a part of the graph in which its direction shows little or no change. The line graph representing Uncle Kees's weight in Figure 1, for instance, consists of five segments.

We now motivate the formulation of structure and linguistic features and show how they are interrelated. In doing so, we hope to exemplify how a linguistic turn in educational design can be realised. We formulated two structure features to meet requirement 2 (the pedagogical genre should help pupils to interpret natural phenomena that graphs represent but also to describe the graphs themselves):

- Pupil interprets each segment of the graph in terms of what happens in reality (S1).
- Pupil describes each segment in terms of the course of the graph (S2).

In the literature we did not find guidelines or information as to the linguistic tools that could help realise such interpretations and descriptions. To actually interpret and describe segments, however, pupils need specific language. Requirement 1 concerns the use of daily, general academic and subject-specific language and led to our design decision to formulate two linguistic features to promote pupils' use of particular types of language for the different purposes of interpreting and describing:

- Pupil includes general academic language in the interpretation of reality (L1).
- Pupil includes subject-specific mathematical language in the description of the course of the graph (L2).

Table 1 Structure and linguistic features of the pedagogical genre

	Structure features	Examples
	A pupil proficient in this pedagogical genre…	
S1	describes each segment in terms of what happens in reality	*Between his 25th and his 30th birthday his weight quickly diminishes.*
S2	describes each segment in terms of the course of the graph	*The graph descends gradually.*
S3	describes the starting point of the line graph	*At the age of 20 Uncle Kees weighs 85 kilograms.*
S4	describes peaks and troughs when present in the graph	*When Uncle Kees is 40, his weight reaches its minimum: about 74 kilograms.*
	Linguistic features	**Examples**
	A pupil proficient in this pedagogical genre…	
L1	includes general academic language in the interpretation of reality	*...his weight decreases quickly*
L2	includes subject-specific mathematical language in the description of the course of the graph	*descends gradually*
L3	distinguishes between gradations (e.g., of steepness) to express mathematical precision	*The graph shows a steep fall.* *The graph descends gradually.* *He slowly loses weight.*
L4	uses words such as *as*, *at*, *in* and *when* to refer to moments in time (i.e. points in the graphs)	*At the age of 20* *In 2010*
L5	uses word combinations such as *from…to*, *between…and* and *from…onwards* to refer to periods in time (i.e. segments of the graph)	*Between his 20th and his 25th birthday* *From 2010 to 2012*

Our review of graph-related literature had focused our attention primarily on the activity of attributing meaning to *segments* of line graphs (across-time reading of graphs), as an activity with which pupils experience particular difficulty. This explains our initial focus on graph segments in the design of the first two structure features and the first two linguistic features. An expert question round conducted during the experimental phase, however, highlighted the importance of pointwise reading in general and the inclusion of starting points, peaks and troughs in particular – critical moments in the natural phenomena represented. The enactment of our lessons indicated that pointwise reading is a prerequisite for understanding across-time phenomena represented in line graphs. We therefore also included the following structure features, concerning points in a line graph:

- Pupil describes the starting point of the line graph (S3).
- Pupil describes peaks and troughs when present in the graph (S4).

In line with literature addressing second language learners' problems with prepositions (e.g., Chodorow, Gamon, & Tetreault, 2010), the empirical data showed that pupils did not have language available with which they could distinguish between *moments* in time (points in the graph) and *periods* in time (segments of the graph). Given the intertwinement of concept development and language development (Sfard, 2008), it is likely that without the linguistic tools to distinguish between moments and periods in time (i.e., points and segments of the graph) pupils will find it difficult to reason with the concepts involved (e.g., an on the spot measurement versus changes over time). We concluded that temporal prepositions (e.g., *from*…*to*, *between*…*and*, *at*, *in*) are key to being mathematically precise in the domain of line graphs, as they allow for adequately distinguishing between moments and periods represented in a graph. Therefore, we designed particular linguistic features to serve as tools with which pupils could adequately refer to and distinguish between moments and periods in time:

- Pupil uses words such as *as*, *at*, *in* and *when* to refer to moments in time (i.e., points in the graphs; L4).
- Pupil uses word combinations such as *from*…*to*, *between*…*and* and *from*…*onwards* to refer to periods in time (i.e., segments of the graph; L5).

As an attempt to meet requirement 3 concerning across-time reading of graphs in relation to the natural phenomena the graphs represent, we felt that we also had to formulate a linguistic feature that would help pupils interpret and describe *gradations* of a line graph's steepness in a mathematically precise way:

- Pupil distinguishes between gradations (e.g., of steepness) to express mathematical ideas with precision, though not yet in numeric form (L3).

Pupils were offered several words to use in the mathematical activity of distinguishing between gradations, for example: *gradually*, *fast*, *slowly* and *steep*. The focus on the structure and linguistic genre features illustrate what we mean by a linguistic turn in educational design: To structure pupils' mathematical activities we need to think through how their linguistic activity of becoming proficient in genres can be designed.

Although in retrospect we think it quite possible that other structure and linguistic features could also function as an aid for primary pupils' reasoning about line graphs, we deliberately restricted the number of features to make the pedagogical genre feasible for the teacher to work with and for the researchers to implement in the design of lessons. This choice is in line with the idea of frugality: being prudent and economical with what needs attention, thus offering simple guidelines without significant loss of inferential accuracy (Gigerenzer & Goldstein, 1996). Thus with the resulting list of features we do not want to suggest completeness. Rather, this set of features offered the teacher a simple list of focal points and enabled the pupils to reason about line graphs. We should thus distinguish between the pedagogical genre itself and the instructional aid of the derived set of structure and linguistic features with examples. For instance, it is well possible to identify additional features such as the tenses used in talking about graphs: We would prefer pupils to use present tense for graph characteristics. However, we saw no need to make this explicit to the teacher or pupils, because pupils made few mistakes and being precise about this did not seem to benefit pupils' mathematical understanding (in contrast to the example about temporal prepositions).

3.4.3 Promoting pupil proficiency in the pedagogical genre

In developing the pedagogical genre throughout the cycles of design research, we embedded the promotion of pupils' genre proficiency in increasingly thorough and systematic ways in the design. We now present three ways in which we capitalised on pupils' pedagogical genre proficiency and briefly illustrate each of these.

The aforementioned *teaching and learning cycle* (e.g., Gibbons, 2002), constituting our framework for action, was used as the main guiding design heuristic to induct pupils in the pedagogical genre of interpretative description of a line graph. In the first phase of this cycle, building the field, the focus was primarily on exploring the domain of line graphs. Therefore, we predominantly followed RME-informed design principles in this phase. In a process in the spirit of guided reinvention pupils were to come up with the line graph as representation in response to a mathematical problem, for example: "will this sunflower reach a length of 3 meters?" As such a problem invoked pupils' exploration of representations that could solve the problem, this allowed for a whole-class discussion resulting in the guided reinvention of the line graph. In such discussions

the teacher particularly focused on concepts (rather than formulations) central to the pedagogical genre, such as *gradually* and *constant* and wrote these on a so-called expanding word list (Smit & Van Eerde, 2011; see also Chapter 2 in this thesis). In the subsequent phase of the teaching and learning cycle, the modelling phase, the structure and linguistic features of the pedagogical genre were explicitly addressed in instructional activities. Examples of such activities included the use of writing frames (in this research also used as speaking frames in whole-class interaction), the use of a writing plan, discussion of pupils' own productions in the pedagogical genre (spoken as well as written), and discussion of model texts written in the pedagogical genre. The purpose of developing pupil proficiency in the pedagogical genre also formed a recurring theme in whole-class discussions and can be summarised as learning to speak and write about line graphs "as mathematicians" (cf. Gibbons, 2006).

To encourage the teacher to support pupil proficiency in the pedagogical genre, she was provided with a *repertoire of strategies for scaffolding language* (see Table 2). This repertoire, constructed to both promote and evaluate the teacher's enactment of language supporting strategies, was developed and refined in three cycles of design research. Its construction was first informed by scaffolding literature, which is for instance reflected in the potentially responsive (adaptive) nature of all strategies. Second, the empirical data inspired its construction, as these informed us on the extent to which strategies seemed effective for promoting pupil proficiency in the pedagogical genre.

Table 2 Strategies for scaffolding language and examples for each strategy

	Strategies	Examples
1	Reformulate pupils' utterances (spoken or written) into more academic wording	[In response to *the graph goes higher and higher up*:] *Yes, the graph does rise steeply.*
2	Ask pupils to be more precise in spoken language or to improve their spoken language	*What do you mean by 'it'?*
3	Repeat correct pupil utterances	*Yes, the graph does descend slowly.*
4	Refer to features of the text type (interpretative description of a line graph)	*Into how many segments can we split the graph?*
5	Use gestures or drawings to support verbal reasoning	For example, physically signalling a horizontal axis when discussing this concept
6	Remind pupils (by gesturing or verbally) to use a designed scaffold (i.e. word list or writing plan) as a supporting material	*Look, the word you are looking for is written down here.*
7	Ask pupils how written text can be produced or improved	*How can we rewrite this in more mathematical language?*

The following interaction fragment from lesson seven in the third teaching experiment illustrates the teacher's employment of the scaffolding repertoire. In this fragment the topic of discussion is a line graph presented on the whiteboard showing Uncle Kees's weight as changing throughout the years (see Figure 1).

Yassin	When he was thirty and thirty-five he just stayed at seventy-six kilograms (points at numbers along the axis).
Teacher	Wait a minute. How can we formulate this in the proper wording? When he was thirty *and* thirty-five? What you, Oussana?
Oussana	Thirty till thirty- five, he just stayed the same.
Teacher	Do we say thirty *till* thirty-five?
Abdul	From.
Teacher	From. From, and now put this in a beautiful sentence. Just face the class, because then this lovely sentence will come out!
Yassin	From thirty till thirty-five Uncle Kees stays constant.
Teacher	From thirty till thirty-five. When Uncle Kees is *between* thirty *and* thirty-five years old, or… *from* thirty *till* thirty-five.
Yassin	Uncle stays, Uncle stays constant, Uncle Kees stays constant.
Teacher	Yes. But do I keep standing "constant"? <u>What</u> remains constant? Remember, I'm Uncle Kees again (acts out Uncle Kees).
Yassin	The kilograms.
Teacher	And how, what was that again? Not my kilograms.
Yassin	Uncle Kees's weight just stays at seventy-six kilograms.
Teacher	Yes. His weight remains the same. As you can tell from the graph?
Yassin	Which remains constant.
Teacher	That's it. Now you have used proper mathematical language. All right. In a few minutes' time we've actually come to know a lot about Uncle Kees, who we haven't even met. By looking at the graph's change in direction. OK.

The teacher's scaffolding of several pedagogical genre features come to the fore in this interaction transcript. At the start of the transcript, the teacher asks for a reformulation when a pupil incorrectly uses temporal prepositions. This relates to the linguistic features of using particular temporal prepositions to refer to either moments or periods in time. Next, the teacher asks a pupil to produce a full sentence independently with adequate use of temporal prepositions ("and now put this in a beautiful sentence").

Subsequently, the use of a structure feature is at stake: whether to use general academic or subject-specific language when interpreting reality, in this case Uncle Kees's weight ("But should *I* keep saying 'constant'? *What* remains constant?"). The teacher reminds the pupils that *constant* is a concept to be used describing the course of the graph rather than in interpretations (at least in this context). Furthermore, the teacher encourages pupils to use more formal wordings when reasoning about line graphs, for example in eliciting the word *weight* ("what was that again? Not my kilograms"), and in reformulating a previous pupil utterance ("his weight remains the same"). The teacher finally explicitly remarks on the use of particular language ("now you have used proper mathematical language") and summarises what knowledge can be gained from describing and interpreting line graphs ("in a few minutes' time we've actually come to know a lot about Uncle Kees, who we haven't even met…").

A key instrument to support pupil proficiency in the pedagogical genre throughout the teaching experiments formed the HLT. In the literature, the overall learning goals formulated in HLTs deployed in design research for mathematics education have so far been confined to *mathematical* ideas that constitute the potential developmental endpoints (e.g., Bakker, 2004; Simon, 1995). We aimed to also include *linguistic* goals in the HLT. At the outset of the study it was not entirely clear what aspects of language use could be designed, even though we aimed to use the design heuristic of the teaching and learning cycle and the instrument of HLT to promote the development of language required for reasoning about line graphs. Only in the emergence of the innovative construct of pedagogical genre and in the actual design of its features did we develop a clearer picture of how language could become the focal point of our lesson designs – of how a linguistic turn in educational design could be realised. Table 3 includes an example of an HLT as formulated toward the end of the third teaching experiment.

Table 3 HLT as formulated before lesson seven in the third teaching experiment

Mathematical and linguistic goals
• Pupils view a line graph as a representation involving different segments (stages) and can determine these segments (stages) independently. • Pupils develop a richer understanding of what points and segments of a line graph represent. • Pupils describe each segment in terms of reality and in terms of the course of the graph, using previously made writing agreements written on the whiteboard. • Pupils describe reality by deploying general academic language (e.g., his *weight decreases slowly*) and they describe the line graph by deploying subject-specific language (e.g., the *graph descends gradually*); in both cases they make use of the growing word list attached on the wall.

Table 3 HLT as formulated before lesson seven in the third teaching experiment

- Pupils can relate words belonging to general academic language to words belonging to subject-specific language in terms of meaning (e.g., the relation between *decrease* and *descend*)
- Pupils can correctly use temporal prepositions (*from…to*; *between...and*; *at*; *in*) for referring to points of the graph (moments in time) or segments of the graph (periods in time).

Starting points
Pupils have been introduced to subject-specific words (constant, axis, etc.). They are familiar with reading off information from line graphs and tables. Pupils have collaboratively constructed graphs themselves. They have difficulty interpreting changing direction in a graph. Pupils have been introduced to the idea that a graph can be divided into segments and that each segment can be described in terms of reality and in terms of direction of the graph. In most cases, pupils include the description of important points (peaks, troughs, starting point) when describing and interpreting line graphs. Some pupils still have difficulty using temporal prepositions to refer to periods or moments in time: *from...to*, *between...and*, *at*, *in*, etc.
Instructional activities
1. Teacher and pupils collectively divide a line graph representing Uncle Kees's weight into segments. 2. Pupils match sentences about Uncle Kees's weight (reality) and the course of the graph with the different segments of the graph, followed by a whole-class discussion. 3. Teacher explains temporal prepositions to the whole class, visually supported by using timelines; whole-class discussion of examples. 4. Pupils conduct a writing activity in which they fill in temporal prepositions in a writing frame containing a text about Uncle Kees's weight in the targeted pedagogical genre.
Assumptions about how the instructional activities support mental activities that lead to the mathematical goals
Ad 1) In discussing how to divide a line graph in different segments, pupils realise that changes in the course of the graph (direction) represent changes in reality. Ad 2) In matching sentences with segments of the graph, pupils' understanding of gradations of steepness in the graph is promoted. Ad 3) By using a timeline in visualising the use of temporal prepositions, which is related to the horizontal axis in the representation, pupils' mathematical understanding of moments and periods in time is promoted. Ad 4) In consciously employing temporal prepositions in the activity of interpreting and describing a line graph, pupils develop conceptual understanding of points versus segments of the graph as well as of changes in the course of the graph.
Assumptions about how the instructional activities support mental activities that lead to the linguistic goals
Ad 1) In discussing how to divide a line graph in different segments, pupils prepare the activity of interpreting and describing a line graph. Ad 2) In matching pre-formulated sentences with segments of a line graph, pupils are provided with "modelled" genre sentences that will foster their genre proficiency. Furthermore, by providing pupils with given formulations, they can focus on and develop their understanding of

Table 3 HLT as formulated before lesson seven in the third teaching experiment

attributing *both* an interpretation *and* a description to each segment of the graph.
Ad 3) Pupils reinforce their knowledge and use of temporal prepositions.
Ad 4) By actively using temporal prepositions in a meaningful context, pupils' (second) language development concerning this aspect of the pedagogical genre is promoted.

Having provided a theoretical and empirical justification for the pedagogical genre, and having summarised how pupil proficiency in the pedagogical genre was promoted, we now evaluate what pupils learned from our approach that focused on promoting pupil proficiency in the pedagogical genre. To this end, we address the following research questions:

1. *To what extent did pupils make progress in deploying the pedagogical genre that we called interpretative description of a line graph?*
2. *How can we characterise the development of pupils' genre proficiency?*

3.5 Methods

3.5.1 Setting and participants

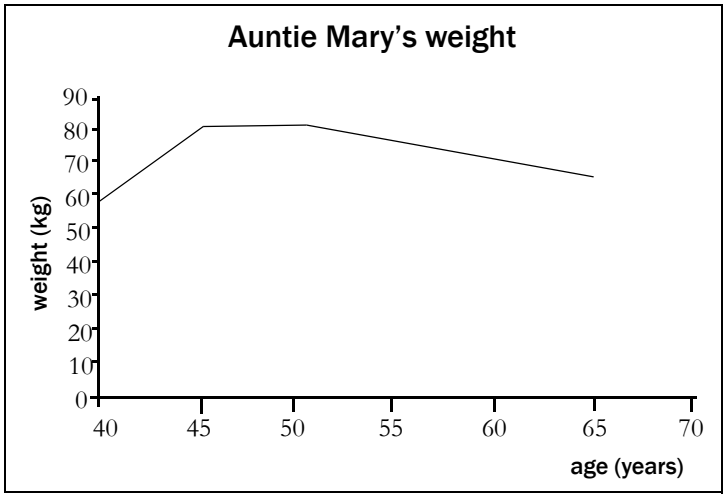
For this part of the paper, we only use data from the third teaching experiment, which consisted of nine lessons. The experiment was carried out in a combined grade 5-6 class of a suburban primary school (age 10-12), with twelve boys and ten girls. Lessons were given weekly and lasted 60 to 70 minutes each. The number of pupils speaking Dutch as a second language was 19 out of 22, the majority being second or third generation Moroccan and Turkish pupils, who performed rather weakly on a standardised test for language (CITO assessment). The teacher, who was not the regular class teacher, had learned to enact language-oriented mathematics lessons in the domain of line graphs in the two previous teaching experiments. More specifically, she had learned to deploy strategies from the repertoire of strategies for scaffolding language (Smit & Van Eerde, 2011).

To answer research question 1, we used data of all pupils. To answer research question 2, we selected four pupils as case-study pupils. A first selection criterion was their bilingual background: They spoke a language other than Dutch with their parents at home. The second criterion was their willingness to participate and talk in interviews (as judged by their class teacher). Third, case-study pupils were to represent different mathematical levels, based on their scores at regular mathematics tests and participation during regular mathematics lessons. Based on these three criteria we selected three pupils to be followed weekly after the lessons: Abdul (low mathematics level), Rabia (average mathematics level), and Moad (high mathematics level). Because Moad turned

out to be quite silent during the early interviews, we agreed with the class teacher and the teacher participating in the experiment to also follow Youness (high mathematics level) from lesson 4 onwards.

3.5.2 Instruments

HLTs were used to design language-oriented lessons in the domain of line graphs (see Table 3 for an example). To identify to what extent pupils made progress in the pedagogical genre (RQ1), we used one task from the pretest and a comparable task from the posttest. These two comparable tasks were chosen to gain insight into pupils' progress concerning productive, independent genre proficiency. Pupils had to describe and interpret a graph such as Figure 1 shows, which took them about 15 minutes (about one third of the total test). Another part of the tests, on receptive language learning, is analysed in Chapter 5 (Smit & Van Eerde, in press). There were eight days between the last lesson and the posttest.



Describe how auntie Mary's weight changes and how you can tell from the graph.

Figure 2 Test item for investigating pupil proficiency in the pedagogical genre

To investigate pupils' development in the pedagogical genre (RQ2) we conducted interviews with four case-study pupils after each lesson. These interviews started with a general list of questions that were asked in each interview. In this way, we aimed to ensure comparability of spoken language utterances throughout the experiment, which would help trace pupils' language development. In the second half of each interview, pupils were posed a number of questions related to subject matter central to the lesson given that day. Examples of questions posed in both parts of the interviews are presented in Table 4.

The scheme for the interviews also included guidelines to steer away researchers from enactment of scaffolding strategies. These guidelines included, for example, "do not reformulate pupils' spoken utterances" and "do not ask for more precise language". Furthermore, questions related to structure features of the pedagogical genre were discouraged, for instance: "You have described the course of the graph, but can you now describe what happened in reality?" By establishing these nonscaffolding guidelines we hoped that we could minimise the learning effect of these interviews.

Table 4 General and lesson-specific questions used for interviews with case-study pupils

General questions	Examples of lesson-specific questions
What was the lesson about?	What kind of image did you come up with to represent Koen's growth?
What did you find difficult or easy this lesson?	I will now read a statement about the graph here (show graph). Do you agree with that? Why or why not?
Which words did you find difficult this lesson?	What did you write down for question 3? How did you get to your answer?
Did the teacher say or explain something that was new to you?	
Did other pupils say or do something from which you learned?	
During the lesson you've been discussing this graph (show line graph). Can you describe what this line graph is about? (from third lesson onwards, from which moment pupils knew to what the question referred)	

3.5.3 Data collection

Data collection used for the analyses presented in this paper included audio and video recordings of nine lessons (all transcribed verbatim), field notes, pupils' pre- and posttest results, as well as their written work. Furthermore, data collection consisted of audio recordings of interviews held with the four case-study pupils after each lesson as well as before and after the teaching experiment. Each interview lasted 10 to 15 minutes and was carried out by two researchers of the research team. All interviews were transcribed verbatim. In those cases where pupils read aloud from their own written work, utterances were presented in between quotation marks. Gestures and comments provided by the researchers were added between parentheses.

3.5.4 Data analysis: pupils' progress in the pedagogical genre (RQ1)

To answer research question 1, we analysed all pupils' writing in the targeted pedagogical genre in pre- and posttest. To this end, we developed an analytic framework for assessing

pupils' written performance in the genre that included scoring instructions and fictitious examples. After several rounds of constructing, testing and evaluating the framework, the final twelve categories of the analytic framework were formulated, capturing all structure and linguistic features of the pedagogical genre. Ten out of 12 categories have an ordinal three-point scoring system (see Table 5). The remaining two categories involved the *counting* of general academic words (e.g., increase, decrease, grow, equal) and subject-specific words (e.g., constant, gradually, rise, descend) that pupils used in their written texts. Therefore, these two categories employed a rational scoring system.

Table 5 Example of a category from the analytic framework

Category	Score	Description for each score	Scoring instruction	Example
Describes the starting point of the line graph	1	The starting point has not been described.	No data involving the starting point of the line graph are included.	
	2	The starting point has been described, but either incorrectly or incompletely	Only one of the two axes is included in the description of the starting point on the line graph.	Uncle Jan weighs 80 kilos.
			One axis is incorrectly interpreted.	Uncle Jan does not weigh much when he is 40 years old.
	3	The starting point has correctly and completely been described	The starting point is correctly and precisely interpreted and included.	At the age of 25 Uncle Jan weighs 80 kilos.

All pupils' line graph descriptions in pre- and posttest were scored by two independent raters using the analytic framework. As a consequence of using two different scoring systems (ordinal and rational), we computed two kappas (one for each scoring system) to determine interrater reliability. According to the $2n^2$ rule (Cicchetti, 1976), we used more than sufficient units for the computation (n is the number of categories, 3 resp. 5). Cohen's kappa, based on 418 ($> 2 * 3^2 = 18$) ordinal units, was .77. Cohen's kappa, based on 88 ($>2 * 5^2 = 50$) rational units, was .78. Both kappas indicate substantial interrater reliability.

To determine pupils' genre proficiency in pre- and posttests, all pupils received a mark (up to 10) for their written graph descriptions, based on the following steps. First, for each unit to be scored the average of two scores attributed by the independent raters was determined. Subsequently, these average scores were multiplied by the weight attributed to each particular category by the researchers. For example, the category of "describes each segment in terms of what happens in reality" was attributed more

weight (3) than the category of "describes the starting point of the graph" (2), because the former relates to a complete line graph, while the latter only relates to one point in a line graph. Last, all weighted scores were added up for each pupil's test and divided by the maximum number of points, resulting in a score (a mark up to 10) for each pupil. Cronbach's alpha computed on the posttest scores was .83, which indicates a good internal consistency. To compare pre- and posttest scores, we used paired-samples *t* tests (normality checked with histograms and Q-Q plots in SPSS). For computing effect sizes, we used Cohen's *d* with pooled standard deviations: mean (post)-mean (pre) divided by the pooled SD.

3.5.5 Data analysis: characterising pupils' developing genre proficiency (RQ2)

To find an answer to the second research question, we traced pupils' developing genre proficiency in a detailed and long-term way. This is in line with Schleppegrell's (2010) recommendation for future research into the role of language in mathematical learning: "We need rich studies of how language and ways of talking about mathematics evolve over a unit of study, focusing on more than brief interactional episodes and fragments of dialogue" (p. 107). A disadvantage of investigating whole-class interaction, in our experience, is that we have little control over who is talking. Rather than focusing on fragments of whole-class interaction in which various pupils always contribute, we presumed to gain deeper insight into pupils' development in the pedagogical genre by tracing the four case-study pupils' proficiencies in the pedagogical genre.

We focused the analysis of pupils' genre proficiency on the following three topics – each including two particular features of the pedagogical genre (see Table 1):

1. The description of each segment both in terms of reality and in terms of the course of the graph (features S1 and S2).
2. The use of general academic language for describing reality and subject-specific language for describing the course of the graph (L1 and L2).
3. The use of temporal prepositions to refer to either moments or periods in time (L4 and L5).

The first two topics are related: Both incorporate the staged character of the pedagogical genre, which is also key to genre teaching more generally (cf. Derewianka, 1990; Martin, 2009). The third topic has been selected for analysis because of the intertwinement of concept and language development that comes particularly to the fore in the linguistic features involved (L4 and L5).

To analyse the four case-study pupils' progress concerning these three topics, we compared the relevant HLTs with observed learning. Table 6 shows the different parts

(columns) of the HLT-informed instrument and provides an example of one pupil's use of temporal prepositions in the interview conducted after lesson 7 (see Table 3 for the designed HLT for lesson 7 and Figure 1 for the line graph discussed).

Table 6 Structure of the comparison of hypothesised learning and pupils' utterances during interviews

Lesson	Activity	Hypothesised learning in PG	Quotes from interviews	Conclusion
7	Whole-class explanation of temporal prepositions, visually supported by using timelines; whole-class discussion of examples	Pupils reinforce their knowledge and use of temporal prepositions and gain a better conceptual understanding of points versus segments in the line graph.	His weight? His weight was first 85 kilograms. Then, yes then he descended very much. Then it was, from his, from his 20th to his 25th he was, he went descending little.	Youness has started to actively use temporal prepositions. If he does so, this is mostly correctly (confirming hypothesised learning).
	Writing activity in which pupils fill in temporal prepositions in a writing frame containing a text about Uncle Kees's weight in the targeted pedagogical genre	By actively using temporal prepositions in a given meaningful context, pupils' (second) language development concerning this aspect of the pedagogical genre is promoted.	Descended gradually. And then from his 25th to his 30th he descended quickly. Then he stays from 30 up and to including 35 he stays gradually, then he stays 76 kilograms. [...]	However, it also occurs incorrectly (up and to including) and mixed with his previous style of "then..." (rejecting hypothesised learning).

In the three analyses carried out we used those instructional activities (as described in the design HLTs) that related to the topic being analysed. In Table 6 this concerns the use of temporal prepositions, which refer to either points (moments in time) or to segments (periods in time). From the interviews we identified all pupils' quotes in which pedagogical genre features were used in a correct, partly correct, or incorrect way. As we conducted separate analyses for the three aforementioned topics, all transcripts of interviews were analysed through three different lenses. As a consequence, some quotes were included more than once. For example, Youness's use of general academic language and subject-specific language (see for instance "he descended very much" in Table 6) was also included in the analysis of topic 2. In the conclusions based on pupils' quotes (see last column in Table 6) one researcher summarised to what extent

hypothesised learning was confirmed. The same researcher formulated a few key aspects of each case-study pupil's development in the particular topic that seemed most typical. These key aspects can be seen as a summary of a pupil's learning process that is based on all separate conclusions drawn for one pupil for each topic. Another researcher from the team read both the conclusions and the summaries. The rare instances of disagreement were discussed until agreement was reached.

3.6 Results

3.6.1 Pupils' progress in deploying the pedagogical genre (RQ1)

The comparison of pre- and posttest scores all yielded statistically significant differences (see Table 7). The effect sizes are very large for all three categories: class as a whole (d = 2.20), without the case-study pupils (d = 1.91) and the case-study pupils only (d = 5.94). Given the small number of case-study pupils (n = 4), we should take the d = 5.94 with a grain of salt. We should also take into account that our intervention lasted for nine lessons, which is longer than experiments on which Cohen (1988) based his distinction in small (from 0.3 to 0.5), medium (from 0.5 to 0.8) and large (> 0.8) effect sizes. There was no significant difference between boys' and girls' progress in the pedagogical genre (t = 0.40, df = 20, p =.69).

Table 7 Comparison of the post- and pretest results on the relevant items

	Pretest M (SD)	Posttest M (SD)	Difference M (SD)	*t*	*df*	95% CI	*p*	*d*
Class (N = 22)	3.73 (0.74)	6.63 (1.71)	2.89 (1.62)	8.37	21	[2.17, 3.61]	< .001	2.20
Without cases (n = 18)	3.78 (0.76)	6.49 (1.86)	2.71 (1.73)	6.64	17	[1.84, 3.57]	< .001	1.91
Cases only (n = 4)	3.54 (0.75)	7.25 (0.47)	3.72 (0.53)	13.97	3	[2.87, 4.56]	.001	5.94

Note 1. The maximum score was 10 for this part of the test.

Note 2. Cohen's d is computed with the pooled SDs. For example, for the whole class $SD_{pooled} = \sqrt{(0.74^2 + 1.71^2)/2} = 1.3175$, so $d = (6.63 - 3.73)/1.3175 = 2.20$

3.6.2 Characterising pupils' developing genre proficiency (RQ2)

In this section, we present the developments of pupil proficiency in the pedagogical genre throughout the lesson series. In Tables 8, 9 and 10 we summarise this development of the four case-study pupils per topic. Interviews after lesson 1 and 2 are not included, as we did not yet ask pupils to independently describe a line graph during these interviews. Hence, the tables below describe pupils' development from interview 3 up to and including interview 9. For Youness, only the development from interview 4

onwards is included. Below each table we characterise pupils' development and compare it with hypothetical learning.

Table 8 Summaries of pupils' development for topic 1 (S1 and S2): Description of each segment in terms of both reality and the course of the graph

	Graph as a whole	Per segment
Rabia	In early interviews inclusion of some (but not all) segments of the graph; after most late lessons inclusion of all segments of the line graph	Only describes the course of the line graph up to and including interview 8 in most cases; in interview 9 interprets reality and describes the course of the line graph for 3 out of 4 segments
Abdul	Up to and including interview 6 inclusion of some (but not all) segments of the line graph; from interview 7 onwards inclusion of all segments of the line graph	Either interprets reality or describes the course of the line graph after most lessons; in interview 7 interprets reality and describes the course of the line graph for all segments
Moad	Throughout interviews inclusion of some (but not all) segments of the line graph; only after lesson 4 inclusion of all segments of the line graph	Either interprets reality or describes the course of the line graph in all interviews
Youness	From interview 6 onwards inclusion of all segments of the line graph	Either interprets reality or describes the course of the line graph in all interviews (except interview 8: provides dual description for all segments)

Pupils increasingly included all segments of the line graph in their deployment of the pedagogical genre. In early lessons, as anticipated in the HLTs, pupils showed difficulty with inclusion of all segments in their interpretative description of a line graph. This particularly held for Rabia (0 segments after lesson 3, so she only gives a description in general terms) and for Abdul (2 out of 4 segments included after lesson 3). Over time, however, the case-study pupils provided increasingly complete interpretative descriptions. An exception is Moad: He did not show a clear improvement throughout time in terms of segments included in his interpretative descriptions.

Concerning the genre features of describing each segment in terms of reality (S1) and in terms of the course of the graph (S2) we conclude that hypothesised learning only to a limited extent corresponded with observed learning: Youness only once and Abdul as well as Rabia only twice (out of eight interviews) included interpretation of reality *and* description of the course of the graph for a segment of the graph. Moad did not describe graph segments in a dual sense during the interviews.

Table 9 Summaries of pupils' developments for topic 2 (L1 and L2)

The use of general academic language for describing reality; the use of subject-specific language for describing the course of the graph of the graph (*rise*, *descend*, *constant*, *gradually*; in Dutch: *stijgen*, *dalen*, *constant*, *geleidelijk*)

	General academic language	Subject-specific language
Rabia	• Tends to draw nonderivable conclusions in daily language, for example "Uncle Kees gets fatter" instead of "Uncle Kees's weight increases" • Does not include much general academic language in her line graph descriptions (does not provide much reality interpretations in her line graph descriptions; see Table 6)	• Increasingly uses subject-specific language to describe line graphs: at first only *descend* and *rise*; followed by *constant* (from interview 2) and *gradually* (from interview 6) • Uses subject-specific language in increasingly differentiated and adequate ways, for example shows emerging word knowledge of *gradually* in interview 4 ("and then there was, like, the gradualness or so…"); uses *gradually* adequately in interview 6 and as such shows ability to distinguish between gradations of the steepness ("it [the line graph] rises very gradually") • Occasionally mixes up word meanings of *descend* and *rise* in written work (discussed in interview 8) • Is very aware of meaning of *constant* from interview 3 onwards • Occasionally uses subject-specific language to interpret reality, for example "Uncle Kees descends with his weight" • Occasionally uses subject-specific language informally or ungrammatically, for example "and at twelve o'clock then it goes descending very much gradually"
Abdul	• Tends to draw nonderivable conclusions in daily language, for example "Uncle Kees becomes fatter" • Tends to include nonderivable causal relations, for example "Uncle Kees started eating more" (when weight increases); "here he does sporting" (when weight decreases); "here he goes sitting again" (when weight increases	• Increasingly uses subject-specific language to describe line graphs: at first only *descend* and *rise*; followed by *constant* (from interview 3 onwards) and *gradually* (from lesson 6) • Uses subject-specific language in increasingly differentiated and adequate ways (e.g., defines *gradually* as "that it just quietly goes up on one line" in interview 4; defines *gradually* as "that it [the graph] goes up a little, or that it goes down a little" in interview 9 • Occasionally uses subject-specific language to interpret reality

Table 9 Summaries of pupils' developments for topic 2 (L1 and L2)

	• Incrementally starts to use general academic language adequately, for example the correct use of *increase* in interview 7 • Increasingly establishes correct word relations in late interviews, for example between *increase* and *decrease*	• Occasionally uses subject-specific language informally or ungrammatically
Moad	• Tends to draw nonderivable conclusions in daily language, for example "Uncle Kees gets fatter" • Uses several general academic words from the beginning onwards, for example "stays the same" • Does not actively use the words *increase* and *decrease* in his descriptions, but is quite able to give a precise definition of these words in interview 8	• Increasingly uses subject-specific language to describe line graphs: at first only *descend* and *rise*; followed by *constant* (interview 4) and *gradually* (interview 6) • Uses subject-specific language in increasingly differentiated and adequate ways • Occasionally uses subject-specific language to interpret reality • Occasionally uses subject-specific language informally or ungrammatically
Youness	• Tends to draw nonderivable conclusions in daily language, for example "Uncle Kees gets fatter" • Does not include much general academic language in his line graph descriptions • Is quite able to give a precise definition of the words *increase* and *decrease* at the end	• Uses *descend*, *rise* and *constant* from interview 4 onwards; uses *gradually* from interview 5 onwards • Often uses *constant* and *gradually* in descriptions, but struggles with meaning of these words until the last interview (utterances indicate Youness's attribution of one and the same meaning to these words; in last interview Youness can adequately explain the difference between *gradually*, "that it goes very slowly up or down" and *constant*, "that it stays on one line [..] that nothing happens") • Occasionally uses subject-specific language to interpret reality • Occasionally uses subject-specific language informally or ungrammatically ("then it went a very little descending")

Concerning pupils' use of general academic language, we concluded that both Rabia and Youness included little general academic language in line graph descriptions. This can be related to their tendency to focus on the course of the graph rather than on

interpreting reality. Furthermore, the fact that general academic language was context-dependent for each activity (e.g., "losing weight"), whereas subject-specific language (*rise*, *descend*, *constant* and *gradually*) was used for each of these contexts cannot be ignored. Observed development thus did not fully correspond to anticipated development.

When interpreting reality, pupils tended to establish nonjustifiable causal relations or tended to draw nonjustifiable conclusions (as also observed by Leinhardt et al., 1990). Confirmations of hypothesised learning were found in occasional (adequate) use of general academic language in later interviews, for instance Abdul's use of *increase*, as well as pupils' capability to provide correct word meanings for *increase* and *decrease* in later interviews (both Abdul and Moad).

Pupils increasingly used subject-specific language to describe the course of the line graph. This corresponded with hypothesised learning. They did this in increasingly differentiated and adequate ways. However, all case-study pupils occasionally used subject-specific language to interpret reality in unconventional ways (as in "Uncle Kees descends with his weight"). When developing proficiency in a new pedagogical genre, pupils need time and space to explore such new ways of using language. Imperfections in deploying the pedagogical genre should in our view rather be interpreted as manifesting language development rather than as deficient employment of the pedagogical genre. We further remark that subject-specific language, although increasingly used by case-study pupils, at several instances in interviews proved conceptually difficult: for example, the difference between *constant* and *gradually*. Despite the continuous attention for these words and underlying mathematical conceptions, all pupils to some extent kept struggling with their meanings.

Table 10 Summaries of pupils' developments for topic 3 (L4 and L5): The use of temporal prepositions to refer to either moments or periods in time

Abdul	• Predominantly uses *first* and *then* during early interviews (also for describing periods), but increasingly expands repertoire with a variety of temporal prepositions to refer to periods in time (particularly *from*…*to*) • Capability to distinguish between moments and periods increases throughout interviews • Occasionally corrects his own (incorrect) use of temporal prepositions • Shows relapses in employment of temporal prepositions (in particular those referring to periods in time)
Moad	• Predominantly uses *first* and *after* during early interviews and only expands his repertoire with *then* and *at* • Only uses moment-describing temporal prepositions throughout interviews, also when referring to periods, (occasional exceptions were found in written work)

Table 10 Summaries of pupils' developments for topic 3 (L4 and L5): The use of temporal prepositions to refer to either moments or periods in time

Rabia	• Predominantly uses *after*, *then*, *first* and *from* (note: without …*to*) in incorrect ways in early interviews, to refer to both moments and periods in time • From interview 6 onwards increasingly expands repertoire with temporal prepositions referring to periods in time (from…to and between…and) • Occasionally corrects her own (incorrect) use of temporal prepositions
Youness	• Predominantly uses *after*, *then* and incorrect combinations with *from* (e.g., *from…and*) in interviews 4 and 5, to refer to only periods in time (note: does not include moments in these descriptions) • From interview 6 onwards increasingly expands repertoire with temporal prepositions that correctly refer to periods in time (*from…to* and *between…and*) • Correctly uses temporal preposition to refer to moments in time ("on the seventeenth of April"), but not before interview 9 • Occasionally corrects his own (incorrect) use of temporal prepositions that refer to periods in time (see quotations in Table 6)

Corresponding with hypothesised learning, pupils increasingly used temporal prepositions to describe points (L4) or segments (L5) on the graph. This implies that they increasingly distinguished between moments (represented by points) and periods (represented by segments) in time. Thus, by adequately using temporal prepositions pupils improved in mathematical precision concerning line graph interpretation. Occasional self-corrections related to the use of temporal prepositions in our view indicate that pupils were increasingly aware of the need to interpret and describe line graphs more precisely, implying that a process of interiorisation was taking place.

Despite all case-study pupils' progress concerning their use of temporal prepositions, they showed differences in the way they developed proficiency. Abdul and Rabia predominantly used moment-related temporal prepositions (e.g., *at*) for interpreting both points and segments in early interviews. Only in later interviews did they start to adequately use temporal prepositions for describing periods in time. Youness, although from the beginning focusing on periods (across-time reading) more than on moments (pointwise reading), continued to use moment-related temporal prepositions for describing periods until interview 6. Remarkably, it is only in the last interview (9) that he correctly referred to a moment in time. Moad stuck to the use of moment-related words, even when referring to periods in time (i.e., when conducting across-time reading).

3.7 Discussion and conclusion

3.7.1 Summary of the chain of reasoning

In our search for shaping language-oriented mathematics education the idea emerged that a linguistic turn in educational design was needed. By this we mean that design researchers and educators need to think through the implications of a linguistic turn in educational research: What can we design to facilitate pupils' development of the language required for learning content subjects such as mathematics? This question is particularly pressing when designing for multilingual pupils. The answer that gradually took shape over the course of three cycles of design research was that we can design pedagogical genres – genres that have been deliberately designed for educational purposes. We hypothesised that becoming proficient in such a pedagogical genre is what these pupils need to gain access to a particular mathematical domain. But is it feasible for pupils to become proficient in such a genre within a limited number of lessons? The aims of this article were to summarise the development of a pedagogical genre and to evaluate what pupils learned from our approach that focused on promoting pupil proficiency in this pedagogical genre.

For the development of the pedagogical genre that we called an interpretative description of a line graph we used the literature on genre pedagogy and on line graphs to formulate three requirements as well as several structural and linguistic features of the genre (S1, S2, L1 and L2). We further interviewed experts in mathematics education on how they thought pupils in grades 5 and 6 should be able to interpret line graphs. Along with different design cycles, this input led to the formulation of further structure and linguistic features of a pedagogical genre for interpreting and describing line graphs (S3, S4, L3, L4 and L5).

To promote pupil proficiency in this pedagogical genre, we used several key ideas from sociocultural theory, in particular scaffolding, but also from genre pedagogy, in particular the teaching and learning cycle (e.g., Gibbons, 2002). Combining these with the practical experience we had gained in previous studies and design cycles, we designed learning activities with accompanying HLTs. These HLTs included mathematical and linguistic goals. We further asked the participating teacher to use a repertoire of strategies for scaffolding language that we had co-developed with her over the past two design cycles.

For the evaluation of pupil proficiency in the pedagogical genre we addressed two research questions:

1. *To what extent did pupils make progress in deploying the pedagogical genre that we called interpretative description of a line graph?*
2. *How can we characterise the development of pupils' genre proficiency?*

In response to research question 1, we conclude that statistically pupils scored significantly higher on the posttest than on the pretest (Table 7). The effect size was very large, Cohen's $d = 2.20$. This indicates that the pupils had become much more proficient in the pedagogical genre over the course of nine lessons. Although this effect size is promising, we note that Cohen's (1988) characterisations of what counts as large effect sizes do not depend on the length of interventions. It can be expected that longer interventions have larger effect sizes than shorter ones. Without a comparison group we further do not make claims about whether our approach leads to better learning results than other approaches. We consider the quantitative results only as an indication of a proof of existence: It is possible to help fifth- and sixth-grade pupils become much more proficient in a pedagogical genre. We consider this finding to be a sign of feasibility of promoting it in classrooms and an initial empirical justification for the construct of pedagogical genre.

In response to research question 2, we conclude that the four case-study pupils showed gradual progress with some falling back over the course of the lessons. By and large their development was in line with what we had intended or predicted in the HLTs. For instance, they all showed progressive capability of using subject-specific language (*rise*, *descend*, *gradually*, *constant*) for describing a course of the line graph. Moad, however, performed better in written pre- and posttests than in interviews. Although he showed a substantial progress in pre- and posttest results (from 4.29 to 7.83), his developing genre proficiency (concerning a few features) was less obvious in his spoken utterances during the interviews. He was, for instance, the only one who did not provide complete graph descriptions (in terms of segments included, see Table 8) toward the end of the lesson series. Furthermore, he did not use any period-related temporal prepositions (e.g., *from…to*) throughout the interviews. His shy and insecure demeanor may explain why he underachieved during the interviews. For none of the four case-study pupils providing graph descriptions in terms of reality (e.g., "slowly loses weight") *and* in terms of the course of the graph (e.g., "descends gradually") had become a habit. In such cases, where hypothetical and observed learning differed, the differences indicate that even more attention and time is needed to support multilingual pupils' learning processes in the required pedagogical genre.

3.7.2 Potential pitfalls of using pedagogical genres and how to avoid them

From the literature on genre pedagogy and language in mathematics education we foresee a few potential pitfalls of using pedagogical genres in the classroom. First, if we consider such a pedagogical genre a norm of how to speak and write in a particular domain, this norm could lead to deficit views on the bilingual learner (Moschkovich, 2010), as it could focus attention too much on language proficiency (Gorgorió & Planas, 2001; Setati & Adler, 2000). Second, teachers and pupils may initially view a pedagogical

genre as a set of words and phrases (Morgan, 2005). Such "static" views have been criticised by scholars who argue that genre pedagogy constrains pupils' self-expression and creativity. As a result it would induce formulaic, empty language use (e.g., Coe, 2002). In Tardy's (2006) words, these countervoices are justifiable and necessary to warn researchers, educators and teachers how not to employ genres. We now argue how the potential pitfalls of genres as norms or being static can be avoided in genre teaching.

The norm issue is related to Adler's (2001) *dilemma of transparency*: the dilemma whether or not to explicitly and visibly focus on mathematical language required in the classroom. Although she acknowledges the potential benefits of learner-centred, implicit approaches as they create space for pupils' creativity and meaning-making, she states that such practices still rely on pupils' communicative competence – thus also ask for, and explicitly focus on, language development. Concerning criticism to genres being used as a norm, we stress that promoting pupils' academic language development, as with other types of instructional endeavors, unavoidably holds a normative nature (Macbeth, 2010). We feel that there is nothing wrong with centralising norms, as long as these norms emerge out of an agreed sense of what can be said or done in a classroom (Van Oers, 2001). To this end we advocate pupils reinventing genre features themselves (cf. Hyland, 2004). During the phase of modelling the genre, for instance, pupils could compare different texts to derive their "own" formulations of genre features. These features, however, still need to be well defined in advance. As Bakker and Gravemeijer (2003) argued from a design perspective: The more autonomy we want to allow pupils, the more we have to invest in planning.

Genre descriptions are inevitably static to a certain extent. We argue that a model-like way of genre teaching is exactly what makes genres teachable. Models, in our case a list of structure and linguistic features with examples, can raise teachers' awareness of the wider pedagogical genre at stake and can function as a reassuring and supportive structure for pupils (cf. Hyland, 2007). The employment of a modelled genre for teaching inherently implies a simplification or distortion of reality. However, this nature of models has been argued to make them pedagogically significant (Garfinkel & Sacks, 1970) as long as teachers and pupils also consider the limits or insufficiencies of such models (Macbeth, 2010). We therefore argue to allow ample time for classroom discussion in genre teaching, to promote a dynamic and explorative way of attending to genres and their features. The joint construction phase has already been argued to offer the flexibility to attain this (Humphrey & Macnaught, 2011). It is here that fashions of speaking and writing as well as the development of mathematical understanding come together in the negotiating interaction between teacher and pupils.

Pedagogical genres are never finished. In our case, the pedagogical genre developed throughout three teaching experiments and it is quite possible that it would continue to develop if we carried out more cycles of design research or if we were to work with other types of pupils. This implies genres are never to be used as rigid formats for teaching. Instead we consider pedagogical genres to be germs for future development, for pupils, teachers and researchers.

3.7.3 Pedagogical genre: an ontological innovation?

As diSessa and Cobb (2004) argued, researchers who develop interventions face the challenge of managing the gap between types of theory on the one hand and design on the other. In this process they can encounter a phenomenon that has so far been implicit and yet consequential for learning. Once this phenomenon has been conceptualised as a theoretical construct – an ontological innovation – it can be useful in generating, selecting and validating design alternatives.

In our study we used different types of theory. Sociocultural theory was used as orienting framework, with ZPD as one of its key ideas. Closely related to ZPD is the concept of scaffolding, which functioned as the key concept in our orienting framework in that it, for instance, generally informed the construction of a repertoire of interactive, genre-promoting strategies to be employed by the teacher. Genre pedagogy constituted a framework for action, in particular its teaching and learning cycle (e.g., Gibbons, 2002). It was combined with another framework for action, RME, to shape the instructional activities concerning the mathematical goals. In the process of designing from these theoretical perspectives, we realised that we were actually designing a new genre. Where the literature focuses on existing genres, outside or inside school, it dawned upon us that particular features of genres can and perhaps should be designed. This particularly holds for structure features, because we can establish particular conventions, even temporarily in preparation of more advance and conventional ways of describing line graphs. This implies that pedagogical genres can be somewhat artificial: The temporary convention to describe each point and segment is not typically done by expert line graph users (e.g., Roth & Bowen, 2003), but is a useful starting point in a pedagogical context. Linguistic features should of course reflect cultural conventions. Hence the features about the temporal prepositions (e.g., *from…to*) are not temporary. Yet the example of *five take away two* used in early arithmetic lessons illustrates that even linguistic features can be temporary and adaptive to pupils' current levels of understanding and language use.

In our case, the theoretical construct of a pedagogical genre emerged as the guiding idea in our design. It cuts across different levels of theory in that it is informed by different bodies of literature and helped us focus on what seemed to be consequential for

learning. As Morgan (2005) wrote, language entails more than vocabulary. The notion of genre in a more educationally phrased definition directs designers' and teachers' attention to a broader range of things that matter. For example, as a complement to linguistic features of a genre there are also structure features such as the stages involved in interpreting and describing a line graph. By formulating a small set of relevant linguistic and structure features, we as design researchers support teachers to help their pupils talk mathematically.

Our pedagogical genre was the result of engineering, that is a process of informed conjectures about what works and testing these conjectures while aiming for frugality in the form of a simple set of features that require attention in teaching and learning. It does not make sense to burden a teacher with features that require little attention; she needs to focus on the most important ones that have positive effects on pupils' development of proficiency in the genre at stake. In this way, we think to have in hand a construct that simultaneously functions as a research tool and a practice tool (cf. Mor & Winters, 2007). It captures our researchers' knowledge in a compact transferable way but also can also function as a pragmatic resource for practitioners. As such it can assist in managing the gap to which diSessa and Cobb (2004) referred. Moreover, it delineates "new competencies that become a focus on instruction" (p. 99). The construct of pedagogical genre further orients designers to scrutinise previously implicit aspects of designing for education, in our case how to structure pupils' linguistic and mathematical activity in a coherent and integrative way. For these reasons we think that the construct of a pedagogical genre shares features with the ontological innovations.

DiSessa and Cobb (2004) argued that ontological innovations could only be characterised as such after multiple research projects. Future research will have to show whether the construct of pedagogical genre along with the theories and practical settings in which it is situated lives up to our expectations and can indeed be characterised as an ontological innovation.

3.7.4 Recommendations and future research

We interpret our findings as reinforcing the idea that a linguistic turn in designing is needed. More research is required to better oversee the implications of this turn for design and teaching. As this study has only yielded one pedagogical genre for one particular domain of mathematics, a recommendation for future research is to design pedagogical genres for other domains too, both inside and outside mathematics. In this way, we hope that their nature can be better specified, and that this can advance our understanding of ways in which pedagogical genres can become part of educational practice, design and research.

In this article we have employed the research instrument of HLT to include not only mathematical (content-bound) but also linguistic learning goals. Our findings show that our approach that focused on pupil proficiency in the pedagogical genre indeed supported pupils' language development. Therefore, we recommend including linguistic goals in the formulation of HLTs. The HLT as presented in Table 3 exemplifies how such formulation of linguistic goals can be done in a domain-specific way (in our case related to reasoning about line graphs).

Concerning teaching we foresee that it will be challenging for teachers to integrate language teaching in the teaching of subject matter. The teacher participating in our study at first experienced a field of tension in integrating language and mathematics. Temple and Doerr (2012) referred to this issue as a teacher's *pedagogical dilemma*: When language becomes the object of attention rather than a means to do mathematics, it may distract pupils from mathematical content. To understand such teacher dilemmas, we think that we should tap into what is underneath: their beliefs and awareness, for instance concerning the role of language in content learning. If teachers remain unaware of the content literacy required for their disciplines (a phenomenon observed by Love, 2009), or if they remain reluctant toward the idea of integrating content and language teaching (Tan, 2011), they cannot be expected to adequately centralise language development in content lessons. Even if teachers are aware of, for instance, multilingual issues, and even if they do believe in a language-oriented approach to content teaching, we think that long-term trajectories of professional development are needed (Smit & Van Eerde, 2011). The teacher participating in our study, although being very positive toward our initial ideas, only retrospectively considered the integration of language and mathematics possible for other teachers, provided a trajectory of "practicing scaffolding" and "intensive professional development" takes place.

A final recommendation concerns the potential benefits of individual attention for pupils. As reported in this article, the four case-study pupils whose genre proficiency was traced participated in weekly interviews (about 10 minutes each). These pupils progressed considerably more in the pedagogical genre than the rest of the class even though in these interviews we tried not to scaffold pupils' language development. To us it seems that any extra attention for pupils' language can pay off. There are many ways in which this could be realised in small-scale, feasible ways. For instance, pupils may get the opportunity to briefly reflect on a lesson in small groups, potentially guided by more capable others. The point we want to address is that seemingly small efforts may have an enormous impact on pupils' language development in the long run.

3.7.5 Conclusion

In this article we have argued that it is necessary to think through the consequences of a linguistic turn in educational design. Our work has pointed to the need for designing pedagogical genres, especially in the context of multilingual classrooms. We consider this notion of pedagogical genre potentially to be an ontological innovation.

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Note

1. Terminology about native and immigrant pupils deserves some attention. By native pupils we mean pupils whose first language is the same as the language of instruction. In the Netherlands, the term 'native' does not have the connotation it has in the USA (Indians as the original habitants of the country). Immigrant pupils in our definition speak another language than Dutch at home – here mainly Moroccan-Arabic, Berber or Turkish. We know this information about the participating pupils on the basis of a brief questionnaire and the class teacher's validation of the findings.

Chapter 4

A conceptualisation of whole-class scaffolding

This chapter is based on:
Smit, J., Van Eerde, H. A. A., & Bakker, A. (in press). A conceptualisation of whole-class scaffolding. *British Educational Research Journal*. doi/10.1002/berj.3007

Abstract

The concept of scaffolding refers to temporary and adaptive support, originally in dyadic adult-child interaction. It has become widely used, also in whole-class settings, but often in loose ways. The aim of this paper is to theoretically and empirically ground a conceptualisation of whole-class scaffolding so that it remains close to the origin of the scaffolding concept, but also provides scope for features not salient in one-to-one interaction. Drawing an analogy with Vygotsky's concept of zone of proximal development we argue why the extension to whole-class settings is justified. We further distinguish three key characteristics for whole-class scaffolding – diagnosis, responsiveness and handover to independence – and illustrate these with examples from a teaching experiment focusing on whole-class scaffolding language[1] in a multilingual mathematics classroom (age 10-12). The empirical data led to a metaphorical distinction between online and offline enactment of key characteristics, during respectively outside whole-class interaction. Diagnoses can namely also be made outside lessons, for instance by reading pupils' work; responsiveness can also be realised in adapting instructional activities; and handover to independence can also be fostered in the design of lessons. In addition to this layered nature (online vs. offline), whole-class scaffolding is often distributed over time. Finally, whole-class scaffolding is cumulative with pupils' independence emerging as the cumulative effect of many diagnostic and responsive actions over time. We suggest these three features are at the core of whole-class scaffolding that is deliberately employed to foster long-term learning processes.

Keywords

Whole-class interaction · scaffolding · responsiveness · handover to independence · zone of proximal development

1. The reader who has already read Chapter 3 might expect the term pedagogical genre. However, Chapter 3 was written after Chapter 4 (and 5). The narrower focus on language rather than genre suffices for the aim of introducing our conceptualisation of whole-class scaffolding.

A conceptualisation of whole-class scaffolding

4.1 Introduction

Scaffolding has become a key concept in many educational areas. It originates from the context of one-to-one problem-solving to conceptualise adults' supportive role in children's learning (Wood, Bruner, & Ross 1976). Since its introduction, many scholars have adopted the metaphor to describe and study a teacher's temporary support that helps pupils to perform a task they cannot complete by themselves and that is intended to bring pupils gradually to a state of competence in which they can complete a similar task independently. This type of classroom scaffolding has been extended to less task-oriented types of scaffolding, such as "cultural" scaffolding (Pawan, 2008) and "social" scaffolding (Nathan & Knuth, 2003; Williams & Baxter, 1996), as well as to scaffolding that occurs in symmetrical groups of pupils, or in peer-peer interactions (see De Guerrero & Villamil, 2000; Fernandez, Wegerif, Mercer, & Rojas-Drummond, 2001). The original concept was also extended beyond a focus on teachers and peers by scholars who include a range of support types such as tools and resources as scaffolding mediators (see Brush & Saye, 2001; Davis & Miyake, 2004).

This article focuses on another extension of the scaffolding concept, namely its application in whole-class situations, as advocated by several scholars (see Hogan & Pressley, 1997; Van Lier, 1996). One setting in which whole-class scaffolding has been investigated concerns multilingual classrooms. Over the last few decades scholars in the field of content-based language instruction (Echevarria, Vogt, & Short, 2008; Gibbons, 2002, 2009) have argued that scaffolding language is a fruitful way of promoting multilingual pupils' development of subject-specific registers needed at school. As this type of language development permanently needs attention, whole-class scaffolding has been advocated (Gibbons, 2002; Hammond, 2001).

The advantages and disadvantages of such concept extension to new areas must be carefully thought through. Palincsar (1998) already warned for atheoretical use of the scaffolding concept. More generally, Bal (2009) argued that the changeability of "travelling concepts" is part of their usefulness provided that they are used neither rigidly nor sloppily. The concept of scaffolding would be used rigidly if we adhered so strictly to the original definitions that temporary adaptive support in whole-class settings cannot be called scaffolding even though it is in the spirit of the original idea. Loose use of the scaffolding concept is the case if it is stretched so far that almost any support in classroom interaction (Meyer & Turner, 2002), or even aspects of classroom organisation, artefacts and sequencing (Anghileri, 2006) are called scaffolding. The latter trend of overgeneralising has

already been criticised by many scholars (see McCormick & Donato, 2000; Mercer & Littleton, 2007; Myhill & Warren, 2005; Pea, 2004; Puntambekar & Hübscher, 2005).

Thus, there is a need for a conceptualisation of whole-class scaffolding that keeps as close as possible to the spirit of the origin of the scaffolding concept, but that leaves room for features not salient in one-to-one interaction. We wanted the conceptualisation to be based not only on a review of the literature, but also on an empirical study. The empirical study consisted of three teaching experiments in which we have iteratively improved our conceptualisation and better enacted whole-class scaffolding. We use data from the third teaching experiment to illustrate the resulting conceptualisation. The aim of this article is to provide this theoretically and empirically grounded conceptualisation for scaffolding in whole-class settings.

4.2 Theoretical background

We now first describe the history and characteristics of the scaffolding concept as commonly used in one-to-one settings. Subsequently, we argue why the scaffolding concept is expandable to whole-class settings on theoretical grounds. Last, we present three key characteristics for whole-class scaffolding which are the starting point for our conceptualisation.

4.2.1 Scaffolding characteristics in one-to-one settings

Wood et al. (1976) summarise scaffolding as "the process that enables a child or novice to solve a problem, carry out a task, or achieve a goal which would be beyond his unassisted efforts" (p. 90). They described six tutor actions that constitute the process of scaffolding: (1) recruiting interest in the task; (2) reducing the degrees of freedom 2 (simplifying the task); (3) maintaining direction toward the goals of the task; (4) marking critical features; (5) controlling frustration; and (6) modelling the preferred procedures by demonstrating, so that the learner can "imitate it back" (p. 98). The adult's adaptive role in this process was explicitly expressed by Wood, Wood and Middleton (1978) in the notion of contingency, which has remained a key aspect of scaffolding in the literature. The process of handing over to independence was first described by Bruner and Sherwood (1976) when analysing a learner's agency in a peekaboo game. Later on, Bruner (1983, p. 60) described this handover principle in another non-educational context of language acquisition at home, as a "process of 'setting up' the situation to make the child's entry easy and successful and then gradually pulling back and handing the role to the child as he becomes skilled enough to manage it."

Over the years, scholars have modified the interpretation of the scaffolding metaphor in different directions, while some aspects remained constant. In a review study focusing on face-to-face interactions, Van de Pol, Volman and Beishuizen (2010) distinguished three scaffolding key characteristics: contingency (also referred to as responsiveness); fading; and transfer of responsibility (also referred to as handover to independence). Some scholars, however, also drew attention to other dimensions of scaffolding. Stone (1998), for example, included the following two aspects in his characterisation. Firstly, the adult draws on a repertoire of methods and strategies for providing support. Secondly, the adult is to diagnose carefully the learner's current level of understanding. The characteristic of diagnosing was also implicitly included in an often cited definition from Maybin, Mercer and Stierer (1992, p. 188, emphasis added):

> It is help which will enable a learner to accomplish a task which they would *not have been quite able to manage on their own*, and it is help which is intended to bring the learner closer to a state of competence which will enable them eventually to complete such a task on their own.

Puntambekar and Hübscher (2005) identified ongoing diagnosis as a key characteristic of scaffolding. They argue that the adult should have knowledge of the child's changing capabilities and understandings while the instruction progresses.

In our endeavour to stick to the original characteristics of scaffolding we chose the labels of diagnosis, responsiveness and handover to independence, for reasons that we explain later in this article. However, we first draw an analogy with the closely related concept of *zone of proximal development* (ZPD; Vygotsky, 1978) to underpin why we think it is theoretically justified to expand the scaffolding concept to whole-class settings.

4.2.2 Expanding the concepts of ZPD and scaffolding to whole-class settings

Vygotsky's (1978, p. 86) most cited definition of the ZPD is:

> It is the distance between the actual developmental level as determined by independent problem-solving and the level of potential development as determined through problemsolving under adult guidance or in collaboration with more capable peers.

The concept of ZPD, which is said to be Vygotsky's "most important legacy to education" (Wells, 1999, p. 313), was first explicitly related to the scaffolding metaphor by Cazden (1979). She was also the first to extend the scaffolding metaphor from its original use in the context of dyadic adult-child interactions to teacher-pupil interactions in classroom settings. Vygotsky (1978) articulated the role of instruction in the ZPD as follows: "Instruction is only useful when it moves ahead of development" (p. 212),

"leading the child to carry out activities that force him to rise above himself" (p. 213). In more recent scaffolding research, this crucial role of the teacher has been advocated by many scholars (see Gibbons, 2002; Gillies & Boyle, 2005; Mercer, Dawes, Wegerif, & Sams, 2004; Wells, 1999) with the learner's autonomy as the ultimate aim (Mariani, 1997; Walqui & Van Lier, 2010). Ever since its introduction in 1976, the scaffolding metaphor has frequently been used to describe how educators can best provide assistance to learners within the ZPD to help them move forward to independence (Jadallah et al., 2011).

However, the ZPD concept is divergently understood (as observed by Lantolf & Thorne, 2006; Wells, 1999). This can probably be explained by the unfinished character of the concept at the time Vygotsky died (Lantolf & Thorne, 2006). That is, only eight of Vygotsky's published works mention the ZPD (Chaiklin, 2003) and these hold characterisations of the ZPD that are inconsistent with one another. Hence, a major challenge in the field of educational theory includes interpreting and deploying the concept in a way that is compatible with Vygotsky's theory as a whole. One such interpretation includes the extension from its use in the context of individual learners to use in the context of groups of learners. Several scholars have theorised upon notions of communal ZPD, group ZPD, group zone, joint ZPD and intermental development zone (see Mercer, 2000; Nyikos & Hashimoto, 1997; Wells, 1999), while others conducted empirical investigations into these (Fernandez et al., 2001; Nathan & Kim, 2009).

Scholars have argued that this extension of ZPD is well compatible with the broader sociocultural theory from which it stems. Guk and Kellogg (2007) noted that employing the most cited ZPD definition has led to many scholars investigating *individual* pupils' ZPD and one-to-one scaffolding, whereas the broader context of Vygotsky's work points at a more social and *whole-class* context for the ZPD. This is in line with Van der Veer and Valsiner (1991), who conclude from chronologically reading Vygotsky's work that his ZPD concept developed from narrow testing contexts to "the general problem of the relation of education and cognitive development" (p. 329). Others also assumed it was possible to establish the ZPD of the class as a whole as it allows us to conceptualise the social distribution of mind (see Wertsch, 1991). This view coincides well with the idea of the social formation of mind that forms the core of sociocultural theory (Wertsch, 1985). From this perspective, contributing to whole-class discussion is essential for knowledge transition from the intermental to the intramental plane (Wells, 1999) as is expressed in the notions of *forum* (Bruner, 1990), *collective work* (Leont'ev, 1978) and *common knowledge* (Edwards & Mercer, 1987).

The analogy with the presumed strength of a group ZPD due to its social mediation underpins the claim that scaffolding may be a powerful teaching strategy in whole-classroom interaction. Theoretical and empirical studies on characterising whole-class scaffolding are rare, but some scholars give directions for conceptualisation. Cazden (1996, p. 175) argued on theoretical grounds that "group scaffolds are conceivable, in which ZPD's for individual members will differ but within a range that makes collaboration in a common effort still possible". Nathan and Kim (2009) empirically investigated whole-class scaffolding by distinguishing teacher utterances in whole-class settings eliciting pupils' lower and higher order thinking. Hogan and Pressley (1997) studied a teacher's whole-class scaffolding strategies in a community of enquiry that fostered pupils' deeper understanding and independent thinking. Although studies like these point to the possibility and necessity of identifying whole-class scaffolding, the definitions and operationalisations used tend to either diverge from the original key characteristics of scaffolding, or do not theoretically justify why the concept of (whole-class) scaffolding is applicable.

4.2.3 Scaffolding characteristics in whole-class settings

Having justified through an analogy with ZPD that the scaffolding concept can be conceptualised at the whole-class level, we elaborate on the three aforementioned characteristics as being applicable and operationalisable in whole-class settings. Diagnosis, firstly, has been implicitly or explicitly included in leading definitions of scaffolding (see Maybin et al., 1992; Wood et al., 1976). Others have claimed diagnosis to be essential for contingency, and thus for scaffolding (Puntambekar & Hübscher, 2005; Van de Pol, Volman, & Beishuizen, 2011). Secondly, in doctrinal interpretations of Vygotsky's work the ZPD is argued to be a diagnostic tool meant to assess the child's current state (Chaiklin, 2003; Lantolf & Thorne, 2006). Acknowledging the strong link between the ZPD and scaffolding thus implies that adaptive support can only be successful if the actual developmental level is diagnosed. Thirdly, promoting teachers' scaffolding asks for explicitly focusing on diagnosing (Van de Pol, Volman, & Beishuizen, 2012). On the spot judgments needed for understanding how to best facilitate pupils' learning (Wells, 1999) are a demanding undertaking for teachers in whole-class settings (Smit & Van Eerde, 2011; see also Chapter 2 in this thesis). Therefore, diagnosing deserves explicit attention if we aim to realise scaffolding in whole-class settings. The act of diagnosing, in our view, need not directly precede the actual adaptive response and should therefore not be blurred into the concepts of contingency or responsiveness, but explicitly distinguished.

The second key characteristic of whole-class scaffolding that we distinguish is *responsiveness* (also referred to as contingency). This broadly used notion best captures

the adaptive nature of scaffolding. Moreover, it is argued to be at the heart of the scaffolding process (Van de Pol, Volman, Elbers, & Beishuizen, in press).

The third key characteristic we distinguish is handover to independence, for this is the ultimate aim of the scaffolding process. In this notion the temporary nature of scaffolding is captured. This temporary nature is sometimes included in the notion of fading (e.g., Van de Pol et al., 2010). We argue that (successful) handover is a process that includes fading of the teacher's support (cf. Puntambekar & Hübscher, 2005), which is why we do not distinguish fading as a separate key characteristic.

When requiring whole-class interaction to have these three characteristics, challenges arise. The most prominent is the often mentioned challenge of working collectively with multiple ZPDs – thus working with multiple layers of understanding and skills (see Hogan & Pressley, 1997; Myhill & Warren, 2005). This makes diagnosing, being responsive, as well as handing over to independence much more complex than in one-to-one settings. In line with Nathan and Kim (2009), however, we view a group ZPD to exist *alongside* individual learners' ZPDs. That is, we do not deny the existence of individual learners' ZPDs in whole-classroom settings, but we do regard, for instance, responsiveness as a characteristic that can also be enacted upon the class as a whole.

4.2.4 Investigating scaffolding language in multilingual whole-class settings

Because we focus on the enactment of whole-class scaffolding *language* in a *multilingual* setting, we briefly discuss these two specificities of this research setting. Both aspects come together in Ohta's (1995) definition of the ZPD in the field of second language (L2) learning: "the difference between the L2 learner's developmental level as determined by independent language use and the higher level of potential development as determined by how language is used in collaboration with a more capable interlocutor" (p. 96). In analogy, De Guerrero and Villamil (2000) argue that scaffolding in the second language would "consist of those supportive behaviours, adopted by the more expert partner in collaboration with the L2 learner that might facilitate the learner's progress to a higher level of language development" (p. 53). As pointed out in Walqui and Van Lier's (2010) *pedagogy of promise*, the Vygotskyan idea of teaching that is oriented towards the development of pupils' future potential is particularly beneficial for second language learners.

Developing a "higher level of language development" is not a simple linear process. Taking a sociocultural perspective on second language learning, we view language development as an ongoing process of participating in situated social dialogue. Second language learners are to become part of a certain community in which they learn to

understand and express the language belonging to that community (Gibbons, 2006). Pupils at school learning subject matter *while* learning a second language are exposed to an even bigger challenge. They need to develop the so-called context-reduced, academic registers used in particular school subjects and at the same time realise academic development in these school subjects. Scaffolding the development of these subject-specific languages is thus essential for participating at school. Moreover, we need to emphasise that scaffolding such development of a second language is a world apart from small-scale problem-solving. The former cannot be done within short episodes of discourse, but needs to be viewed against a background of longer periods of time. We include this long-term dimension in our conceptualisation of whole-class scaffolding. We now describe and illustrate how key characteristics of whole-class scaffolding were enacted in our third teaching experiment.

4.3 Origin of the empirical data

In this section we describe the research setting of the design experiment that we drew on for conceptualising whole-class scaffolding. In the next section we discuss the enactment of the three scaffolding characteristics: diagnosis, responsiveness and handover to independence. These are subsequently illustrated by examples from the third teaching experiment from a dual design research project. This type of design research focuses on both teachers' and pupils' learning (Gravemeijer & Van Eerde, 2009; Smit & Van Eerde, 2011).

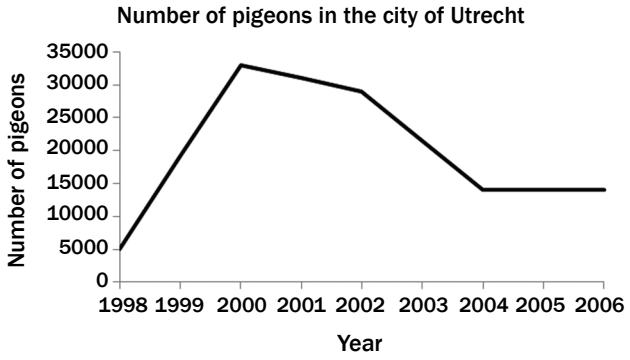
4.3.1 Setting and participants

The teaching experiment was carried out in the last two years of a suburban primary school (age 10-12). Based on the two previous teaching experiments, nine lessons were given with a focus on scaffolding the language needed for reasoning about line graphs. Lessons were given weekly and lasted 60 to 70 minutes. The number of pupils speaking Dutch as a second language was 19 out of 22, the majority being second or third generation Moroccan and Turkish pupils. The teacher, participating in all three teaching experiments, had 17 years of experience in primary education, partly in multilingual classrooms.

4.3.2 Lesson design

As we aimed to promote the enactment of whole-class scaffolding language in a specific mathematical domain (line graphs), we needed to (re)design lessons that would foster this in a classroom setting. To this end, we employed the teaching and learning cycle (see Derewianka, 1990; Gibbons, 2009). This cycle consists of a series of four stages in which a particular text type needed at school is introduced, modelled, jointly practised and eventually individually performed by the pupils. In our study, the "text type" we aimed

for pupils to develop was an interpretative description of a line graph (see Figure 1). During the first three stages of the teaching and learning cycle, especially in the modelling stage, instructional activities are designed so as to promote independence in speaking and writing. Gibbons (2009) refers to the use of such materials as designed scaffolding.



In 1998 there are about 5,000 pigeons in Utrecht. Between 1998 and 2000, the number of pigeons rises considerably; the graph shows a steep increase. In 2000, the number of pigeons gets to its maximum: about 32,000. After that time, until 2002, the number of pigeons drops little by little. The graph descends gradually. After 2002 the number of pigeons drops further down; the graph shows a decrease. From 2004 onwards the number of pigeons stays more or less the same. You can tell because the graph is constant.

Figure 1 Line graph and accompanying text type

Another means to promote whole-class scaffolding of language was the employment of a conceptual framework consisting of strategies for scaffolding language considered to be successful in the first two teaching experiments. This framework was used to promote and evaluate the teacher's scaffolding performance. For examples of such strategies see Table 1.

Table 1 Strategies for scaffolding language and examples for each strategy

1	Reformulate pupils' utterances (spoken or written) into more academic wording	[In response to *the graph goes higher and higher up*:] *Indeed, the graph rises steeply.*
2	Ask pupils to be more precise in spoken language or to improve their spoken language	*What do you mean by "it"?*
3	Repeat correct pupil utterances	*The graph descends slowly indeed.*
4	Refer to features of the text type (interpretative description of a line graph)	*Into how many segments can we split the graph?*

Table 1 Strategies for scaffolding language and examples for each strategy

5	Use gestures or drawings to support verbal reasoning	For example, gesturing a horizontal axis when discussing this concept
6	Remind pupils (by gesturing or verbally) to use a designed scaffold (i.e., word list or writing plan) as a supporting material	*Look, the word you are looking for is written down for you here.*
7	Ask pupils how written text can be produced or improved	*How can we rewrite this in more mathematical wording?*

4.3.3 Data collection

Data collection included video-recordings of all lessons, pupils' written work, the teacher's weekly written reflections using a reflection format we gave her (Appendix D), and audio recordings of video-stimulated recall interviews (SRIs) the researchers held with the teacher between lessons (Smit & Van Eerde, 2011). The idea behind SRIs is to encourage the teacher to think out loud while observing videos of her own lessons, thus to stimulate the teacher to relive the lesson (Meijer, Zanting, & Verloop, 2002). The SRIs followed a set order of question types: (1) neutral questions (e.g., "What happens in this fragment?"); and (2) scaffolding-related questions (e.g., "Why did you respond the way you did?", "What scaffolding strategy did you enact here?"). We always ended with discussing the reflection the teacher had written between lessons to return to her own diagnoses of pupils' written work and oral language, and to discuss scaffolding intentions for the next lesson.

4.4 Enactment of key characteristics

All three characteristics of whole-class scaffolding can in our view be promoted *during* whole-class interaction as well as *outside* classroom interaction (mostly implying between lessons). The former we have metaphorically named *online* and the latter *offline* enactment of key characteristics. The terms online and offline should therefore not be taken literally as being or not being connected to the Internet. We now describe online and offline enactment of all key characteristics.

4.4.1 Diagnosis

Part of the diagnosing process took place during classroom interaction. This *online diagnosing* pupils' actual levels of language development was often a tacit activity, as opposed to situations in which explicit diagnostic strategies might be needed to gain insight into pupils' thought processes (Van de Pol et al., 2011). The SRIs served to make the teacher's tacit diagnoses explicit.

In our research setting, *offline diagnosing* was promoted by asking the teacher to read all pupils' written work between lessons and to make weekly notes on pupils' language development.

The teacher also listened to audio-tapes of half the lessons. In addition, the teacher was asked to fill in a reflection form after each lesson, in which we posed her some diagnosing-promoting questions, for instance: What did you notice about the quality of pupils' linguistic utterances? Furthermore, the researchers diagnosed the pupils' level of language development by watching video recordings and by examining pupils' written work. We discussed our findings with the teacher in preparation for the next lesson. The teacher occasionally formulated "new" diagnoses when watching video recordings as part of SRIs.

4.4.2 Responsiveness

Online responsiveness is seen in a teacher's utterances adapted to pupils' spoken and written utterances, in this case aiming for the development of language. A teacher's utterance can be a direct response to pupils' language, but can also be a response to pupils' language that stems from earlier classroom interaction (e.g., a previous lesson). To promote online responsiveness, the teacher was asked to build up a repertoire of strategies that we formulated in the conceptual framework for scaffolding language. In SRIs the teacher and the researchers evaluated classroom interaction by use of this framework to promote internalisation of the repertoire.

Offline responsiveness was enacted by adjusting lesson designs between lessons, drawing on diagnoses during and after lessons formulated by the teacher and the researchers. Although the plan for the lesson series was designed before the start of the teaching experiment, the instructional activities for each specific lesson were responsive to these diagnoses. That is, when specific language-related difficulties were diagnosed during a lesson, in written work, or when viewing a lesson afterwards, these issues were addressed in a subsequent lesson.

4.4.3 Handover to independence

In an attempt to foster *online handover* we encouraged the teacher to discuss the use of subject-specific language at a meta-level ("Why are we actually trying to be precise here?") and to promote pupils' use of the language aimed to develop ("Now see if you can describe this first segment of the graph in mathematical language yourself"). In this way, we aimed to foster pupils' engagement concerning the use of precise, subject-specific language, as well as to promote their initiative to express themselves at the linguistic level that has just come within reach. *Offline handover* was fostered by employing the teaching and learning cycle. In the first three stages of the teaching and learning cycle, the instructional activities are designed to gradually handover to independence in speaking and writing. An example from our teaching experiment includes the "growing word list" which is used by the teacher to write down subject-specific words (e.g., horizontal axis, coordinate system) and to refer to subject-specific words during whole-

class interaction. Pupils, in turn, can look up the words they need to express themselves mathematically and to ultimately internalise these subject-specific words. Another instructional activity fostering independence is a writing frame (or "cloze" exercise), which supports the writing of subject-specific texts. Here, specific parts of a description of a graph are left out so that pupils get to discuss the meaning and form of the missing words, while still obtaining temporary textual support. This is in line with what Wood et al. (1976) called reducing the degrees of freedom. Once pupils demonstrate increased independence, the writing frames become more "open" (more words are left out) and finally pupils are to verbalise or write the target text independently in new contexts.

4.5 Illustrations of whole-class scaffolding

We consider *diagnosis* the starting point for planning and realising whole-class scaffolding. The scaffolding example given below will illustrate how diagnoses were recurring starting points for online and offline *responsiveness* but also how the process of *handover to independence* was taking place. The linguistic issue used in this whole-class scaffolding example concerns the use of temporal prepositions referring to a particular *moment* in time, represented by a *point* in the line graph (e.g., *at* 6 o'clock, see text below graph in Figure 1) and word combinations referring to a particular *period* in time, represented by a *segment* of the line graph (e.g., *between* 6 *and* 8, see text below graph in Figure 1). We want to emphasise that this focus on particular formulations serves well to illustrate our conceptualisation of whole-class scaffolding but is only a small part of the language scaffolded in the teaching experiment. Our main efforts were also directed towards supporting concepts such as coordinate system, axis, graph, rise and fall, constant, steeply and gradually, and towards the reasoning involved in explaining how graphical features relate to processes represented in the graph.

During the fourth lesson of the teaching experiment one of the researchers observed pupils' difficulty with the use of temporal prepositions. Prepositions are particularly hard to master for second language learners due to their variability in usage (see Bitchener, Young, & Cameron, 2005; Chodorow, Gamon, & Tetreault, 2010). The following pupil's utterance, in which an incorrect preposition is used, illustrates this:

> With 13 weeks the sunflower is growing less fast. [The correct formulation, translated from Dutch, would be: From 13 weeks…]

In the SRI following Lesson 4, the researcher shared her diagnosis with the teacher:

> Pupils say with 13 weeks when they refer to a period, instead of from 13 weeks. They are probably not aware of the difference between words that describe moments in time and words that describe periods in time.

In response to this diagnosis the researchers designed an instructional activity in which pupils were to reformulate sentences containing mistakes in the use of temporal prepositions that pupils had made themselves in spoken language or written work. To not discourage them, these sentences were discussed anonymously in a PowerPoint presentation and attributed to an imaginary child, Piet Praatjens (Tom Talkative). We asked the teacher to discuss these sentences in a non-judgemental way ("How does that sound?" or "How could we say that slightly more precisely?"). The teacher was asked to model the use of temporal prepositions we were aiming to develop during this activity, without explicitly explaining their use. At that time we presumed that implicitly focusing attention on words like these would be enough to activate linguistic knowledge we supposed pupils to have already.

In the SRI following Lesson 5, the teacher diagnosed:

> Words like from and between belong to the language of schooling, right? I had never expected these words to be in need of so much attention. Pupils find it very hard to use these words correctly.

For Lesson 6, a writing frame exercise was designed to support the pupils in developing the text type aimed for. Surprisingly, when discussing the pupils' written answers in a whole-class discussion, the teacher did not notice pupils' mistakes in their use of temporal prepositions, even though this use was meant to be the focus of discussion in the instructional activity.

> Imana: From November two thousand and seven and January two thousand and eight more birds perched along the Northern Coast. The graph shows an increase.
>
> Teacher: OK. [Moving on to the next sentence without reformulating preceding utterance]

Drawing on pupils' written work in Lesson 6, the teacher diagnosed in her written reflection that many pupils did not perform well in the writing frame exercise. In the SRI following Lesson 6 she stated: "Many pupils have not given the correct answer in the written work". She also herself concluded that her own actions had not been optimal and formulated an intention for the subsequent lesson.

> My own explanation for the use of from was confusing for pupils. I shouldn't have done it that way. Next time I will explain these words again, supported by drawings. Also, I will write down correct answers on the whiteboard.

When watching video fragments the teacher realised she had not listened carefully enough to the pupils and had thus missed chances for online responsiveness. She then

declared the intention to listen very carefully to the form of their linguistic utterances in the subsequent lesson.

The interaction fragment from Lesson 7 presented below illustrates the teacher's increased online responsiveness related to the use of temporal prepositions. In this fragment the topic of discussion is a line graph presented on the whiteboard showing Uncle Kees's weight as changing throughout the years.

> Yassin: When he was 30 and 35 he just stayed at 76 kilograms (points at numbers along the axis).
> Teacher: Wait a minute. How can we formulate this in the proper wording? When he was 30 and 35? What you, Oussana?
> Oussana: 30 till 35, he just stayed the same.
> Teacher: Do we say 30 till 35?
> Abdul: From. […]

During Lesson 7 the teacher stated: "So just use *from…to.* We do not say *from… towards.* You cannot say that. It is not what we call 'proper Dutch'". One of the pupils responded to this by saying: "But almost everybody says so." At this point, the teacher initiated a discussion on why the precise use of words like these is actually important. After several pupils' contributions, one boy explained: "Then people start talking good language with you. Then they talk 'social language' to you or something like that." In this quote the boy demonstrates awareness of the fact that specific language use is associated with specific communities. In the SRI following Lesson 7, the teacher stated that she thought it quite poignant to observe these pupils growing more conscious of the social disadvantage of not being able to express themselves adequately. At the same time, she was touched that this issue could be discussed in such an open way, and she was very convinced about all pupils sharing these thoughts and questions.

In the same SRI the teacher diagnosed:

> We explain and practise the use of these words extensively, yet they still make mistakes. I had expected they would fill out the written exercise without experiencing any difficulties, as we explained them repeatedly. By myself, I would never have paid so much attention to words like these.

In response to this diagnosis, the researchers designed an activity for Lesson 8 in which the use of temporal prepositions was again topic of attention. Pupils then started to independently use these words correctly in spoken and written language. The teacher diagnosed after reading the written work carried out in this lesson:

> They have performed much better in their written work, much better than last week. This written work made me really happy! The first part of the joint construction activity went well, but I think we can attribute this progress mainly to the first activity in Lesson 8.

From the next statement we can also derive her intention to take the next step in the process of handover to independence. "I will now only refer to the words by pointing at the supporting drawings on the white board, as we have discussed them before."

Pupils' pre- and posttests indeed show an increase of (correct) use of temporal prepositions. Whereas none of the pupils used these words in the pretest in a description of a line graph, in the posttest 8 out of 22 pupils did use them. Out of these eight pupils, four sometimes used these words correctly and four always used them correctly. For some other linguistic aspects scaffolded during the lessons, the process of handover to independence seemed to have reached a further stage. For instance, the posttest showed that 16 out of 22 pupils were familiar with the names of the axes (horizontal and vertical), compared to 1 out of 22 in the pretest. These examples illustrate that the handing over of seemingly simple linguistic issues can be a long-term process.

4.6 The nature of whole-class scaffolding

The enactment of whole-class scaffolding, as illustrated in the previous section, made us aware of three features that we think are typical of whole-class scaffolding: its *layered*, *distributed* and *cumulative* nature.

4.6.1 Layered nature

Although some scholars argue that scaffolding is an interactive process, the teaching experiment we draw on illustrates that all three characteristics operate on different levels: not only at the interactive level of whole-class discussion, but also outside whole-class interaction, often in between lessons. In Figure 2 these are represented as two different layers, online and offline.

Diagnosing (D in Figure 2), to start with, was often tacitly enacted by the teacher during lessons (online enactment), but was also carried out by the teacher and the researchers in between lessons (offline enactment), for instance when reading pupils' written work and when viewing video fragments.

Concerning responsiveness (R in Figure 2), we see a division between instructional materials and the teacher. That is, offline responsiveness comprises all responses to diagnoses that are "outsourced" to instructional activities (that respond to diagnosed

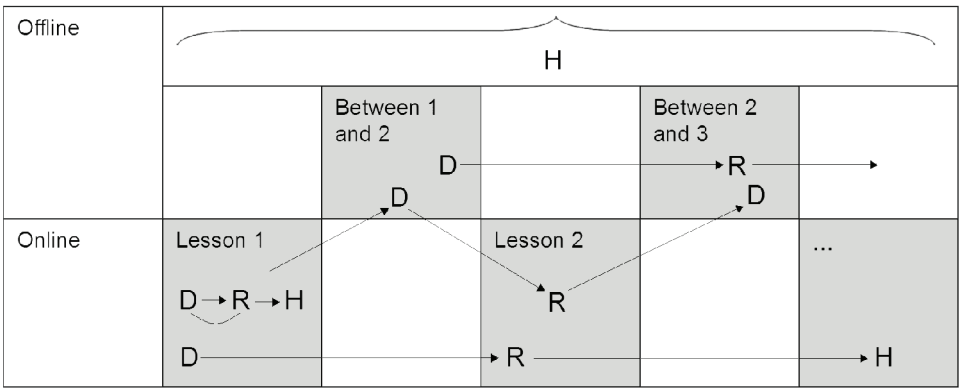


Figure 2 Schematic representation of whole-class scaffolding characteristics: diagnosis (D), responsiveness (R), handover to independence (H)

difficulties) and artefacts (e.g., word list, writing frame). This type of responsiveness was initiated in between lessons. To promote the teacher's online responsiveness we used a framework of scaffolding strategies (see Table 1). We conjecture that such a means of promoting scaffolding can foster the construction of an internalised repertoire that forms the basis for online responsiveness (cf. Stone's 1998 remark on a range of types of support).

Offline handover to independence (H in Figure 2) was realised by drawing on the principles of the teaching and learning cycle for the design of instructional activities and materials. The teacher's role towards online handing over was to invite pupils to formulate independently. In the online row (Figure 2) H refers to the moment that pupils can indeed do so.

4.6.2 Distributed nature

A second feature of whole-class scaffolding is its *distributed* nature. Although we could identify all three key characteristics in our study, they mostly occurred in a scattered way, not within one episode but distributed over several episodes. For example, diagnoses of pupils' performance in written work were responded to in a lesson design for a subsequent lesson (see the arrow between D and R in the offline row). Or, diagnoses during a lesson could lead to increased responsiveness in the next lesson (see the arrow between D and R in the online row). We do realise that up to now responsiveness has mostly been studied at a micro-level of interaction episodes that occur within one lesson – hence the more common term *contingency*. However, if we are to acknowledge the temporal dimension of classroom dialogue (Mercer, 2008), as well as the complex nature of some educational objectives (e.g., learning a subject-specific second language) we also advocate macro-perspectives. These are often related to the preparation for a subsequent

lesson, for which the term contingency seems less appropriate given the deliberate process of designing and the more reified nature of design.

4.6.3 Cumulative nature

In relation to this distributed nature, the *cumulative* nature as a third feature comes to the fore. The example of temporal prepositions tells us that repeated diagnosing as well as repeated offline and online responsiveness initiated and sustained the process of handing over to independence. This too implies that handing over to independence can often not be realised in one and the same lesson, and that pupils' learning processes cannot be attributed to instances of responsiveness. Instead, we would argue that pupils' learning processes represent the cumulative effect of scattered diagnoses, as well as online and offline responsiveness over time.

4.7 Discussion

The aim of this article was to provide a theoretically and empirically grounded conceptualisation of whole-class scaffolding. We intended to adhere to the spirit of the original concept of scaffolding in our conceptualisation for whole-class settings. Hence, we have chosen to distinguish three characteristics which stem from the literature on scaffolding and which in our teaching experiments also proved key in whole-class settings: diagnosis, responsiveness and handover to independence. In this respect, our conceptualisation remains close to the original spirit of what scaffolding is in one-to-one settings. The enactment of whole-class scaffolding, however, made us aware of three features that we think are typical of whole-class scaffolding: its *layered*, *distributed* and *cumulative* nature. We assume that these features hold for any whole-class scaffolding of learning that requires careful design and long-term learning processes.

For our conceptualisation of whole-class scaffolding we drew on a teaching experiment in the context of scaffolding *language*. Although, like any context, this context brings along its own specificities, we see no reason why the scaffolding characteristics would not apply the way they did here when more content-oriented whole-class scaffolding is investigated. However, the enactment of whole-class scaffolding may then need different means. For example, another approach to realise offline handover than the teaching and learning cycle may be needed, because this cycle is specifically aimed at language development. Future research on whole-class scaffolding in various settings is needed to test our assumption.

As to the research setting described in this article, one may wonder how realistic the enactment of whole-class scaffolding would be in naturalistic educational settings.

Admittedly, the researchers played an active role in the offline enactment of the scaffolding characteristics, necessary to promote and investigate whole-class scaffolding. It is unrealistic to assume that teachers would do everything we did in this research setting, but this might not be necessary either now we have insight about what whole-class scaffolding is and how it can be enacted. Although SRIs, for instance, are not likely to happen without researchers or teacher trainers around, it is very well possible that teachers read pupil work in between lessons and discuss a video of their lesson with a colleague. It is also conceivable that once teachers, as part of their professional development, become more capable of enacting offline characteristics systematically and adequately, researchers or teacher trainers can fade away.

What we consider our main theoretical contribution to the field of scaffolding research is (1) the theoretical justification of whole-class scaffolding; (2) a distinction between online and offline enactment of its key characteristics; and (3) the identification of the layered, distributed and cumulative nature of whole-class scaffolding. The analysis of whole-class scaffolding poses methodological challenges: Singular teacher actions during whole-class teaching cannot be characterised as scaffolding since they will usually not have all three characteristics at the same time. Rather, whole-class scaffolding seems to consist of configurations of teacher actions, instructional means and the intention eventually to handover to pupils' independence across lessons. We are not claiming that short-term and one-to-one scaffolding in a problem-solving context cannot be layered, distributed and cumulative. In fact it may well be. But these features are much more apparent in whole-class scaffolding that is deliberately and explicitly employed to foster long-term learning processes.

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Chapter 5

What counts as evidence for the long-term realisation of whole-class scaffolding?

This chapter is based on:
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Abstract

To promote whole-class scaffolding of mathematical language, a teacher was encouraged to employ a repertoire of seven strategies (e.g., reformulating) in a multilingual primary classroom (22 pupils; aged 10-12). This paper investigates whether the enactment of these strategies has led to long-term whole-class scaffolding as identifiable by its key characteristics: diagnosis, responsiveness and handover. Comparison of pupils' pre- and posttest scores on three linguistic key elements all yielded statistically significant differences with large effect sizes, thus confirmed handover. A statistically significant shift from high-support to low-support strategies revealed responsiveness to pupils' levels over nine lessons. A qualitative analysis showed interrelatedness of performed strategies and scaffolding characteristics (e.g., diagnosis). The results provide empirical evidence of the long-term realisation of whole-class scaffolding.

Keywords

Handover to independence · responsiveness · scaffolding · whole-class interaction

What counts as evidence for the long-term realisation of whole-class scaffolding?

5.1 Introduction

The metaphor of scaffolding originates from the context of problem solving to conceptualise adults' supportive role in dyadic adult-child interaction (Wood, Bruner, & Ross, 1976). Scaffolding nowadays refers to the temporary, responsive support that helps a pupil perform a task he cannot yet complete by himself and that is intended to bring the pupil gradually to a state of competence in which he can complete a similar task independently (Jadallah et al., 2011). Ever since its introduction, there has been a growing body of research investigating how to describe, enact and analyse scaffolding (Lin et al., 2012; Van de Pol, Volman, & Beishuizen, 2010). Along with its increasing popularity, the concept has been extended to a variety of settings other than one-to-one teacher-pupil interaction. One complex educational context for which it is advocated is the whole-class setting (e.g., Hogan & Pressley, 1997). Research on whole-class scaffolding, however, faces conceptual and methodological challenges.

5.1.1 Conceptual challenges

Concept extension can lead to overgeneralisation and loose use of the concept if not thought through carefully. Overgeneralisation is involved when the concept is stretched so far that almost any support in classroom interaction (e.g., Meyer & Turner, 2002), or even classroom organisation, artefacts or sequencing (e.g., Anghileri, 2006) is referred to as scaffolding. This trend has been widely criticised over the last decade (e.g., Puntambekar & Hübscher, 2005). Loose use is the case when the concept of scaffolding is used in classroom studies without explicit reference to its key characteristics (as is the case in Jadallah et al., 2011).

In response to these conceptual challenges faced in research on whole-class scaffolding, we have proposed a conceptualisation of whole-class scaffolding that is both theoretically informed and empirically grounded (Smit, Van Eerde, & Bakker, in press; see also Chapter 4 in this thesis). Based on the scaffolding literature, three key characteristics of whole-class scaffolding are distinguished: diagnosis, responsiveness (the adaptive core of the support provided) and handover to independence. These characteristics serve to identify teaching in whole-class settings as whole-class scaffolding. Based on a teaching experiment in which whole-class scaffolding was enacted, we formulated three features of whole-class scaffolding that capture its nature and that distinguish whole-class scaffolding from small-scale scaffolding as conceptualised in the literature up to now. (1) In the first place, we metaphorically

distinguished between *online* and *offline* enactment of key characteristics, during respectively outside whole-class interaction (layered nature). Analysing pupils' work between lessons is an example of offline diagnosis. An example of offline responsiveness is adapting instructional activities between lessons. Offline handover to independence is fostered in the design of lessons. (2) In the second place, key characteristics appeared to occur not in one single episode of classroom interaction, but distributed over several episodes (distributed nature). For example, diagnosing during a lesson can lead to responsiveness in a subsequent lesson. (3) Last, pupils' increase in independence has been conceptualised as the cumulative effect of several instances of diagnoses and responsiveness over time (cumulative nature). Our conceptualisation aimed to address the aforementioned conceptual challenges.

5.1.2 Methodological challenges

Several studies have yielded frameworks or categorisations of scaffolding focusing on teacher actions, but without studying effects on pupils (e.g., Nathan & Knuth, 2003). Scaffolding, however, is relational by nature. If studies do include pupils' progress, it is often unclear how teachers' strategies are related to pupils' development. In other words, teachers' adaptation of support to pupils' level of knowledge or ability needed for pupils' learning is rarely investigated in such studies. Yet responsiveness (also referred to as contingency) has been argued to be the most distinctive characteristic of scaffolding (e.g., Van de Pol et al., 2012). Moreover, explicit attention to teachers' diagnosing pupils' levels is also rare (an exception is Van de Pol, Volman, & Beishuizen, 2011). If we intend to do justice to the relational nature (between teacher and pupils) of whole-class scaffolding (e.g., Rasku-Puttonen, Eteläpelto, Arvaja, & Häkkinen, 2003) we face the methodological challenge of analysing diagnosis, responsiveness and handover also in relation to each other (cf. Mercer & Fisher, 1992). We only assert whole-class scaffolding if a teacher diagnoses pupils' linguistic levels and responsively performs strategies, with indications of handover as a result.

An implication of this choice is that units of analysis larger than brief fragments of classroom interaction are typically needed, as "the process of teaching and learning in school has a natural long-term trajectory" (Mercer, 2008, p. 33). As a consequence we need to analyse classroom interaction as "linked chains of interaction" (Scott, Mortimer, & Aguiar, 2006, p. 610).

5.1.3 The current study

In a design-based research project we have developed a set of strategies for scaffolding the development of subject-specific language needed for mathematical learning, in an attempt to enact whole-class scaffolding (Smit & Van Eerde, 2011; see also Chapter 2 in

this thesis). In the current paper we deal with methodological challenges in the context of scaffolding in whole-class settings. Our aim is to investigate whether the enactment of strategies intended to scaffold the development of subject-specific language in an upper primary mathematics classroom has led to whole-class scaffolding as identifiable by its key characteristics, taking into account the aforementioned long-term nature of whole-class scaffolding. To fulfil this aim we address three research questions in response to the aforementioned methodological challenges.

1. *To what extent did handover to independence take place?*

To determine whether whole-class scaffolding has taken place, we need to find evidence of a process of handover to independence. Unlike most scaffolding studies that focus on the development of reasoning skills or content knowledge (e.g., Nathan & Kim, 2009; Speer & Wagner, 2009), our focus of independence is on subject-specific language development. Scaffolding language has been advocated particularly in multilingual classrooms, and has been argued to be a prerequisite for second language learners' successful participation at school. A reason put forward is that the development of subject-specific language is intertwined with conceptual development in a particular school subject (e.g., Gibbons, 2002). In our case, a process of handover concerned pupils' development of subject-specific language needed for reasoning about line graphs.

Finding evidence of handover to independence only, however, does not sufficiently underpin the assertion of scaffolding. We therefore also investigate the characteristic of responsiveness in relation to performed teacher strategies:

2. *What evidence of responsiveness can be identified in the teacher's enactment of strategies for promoting language development?*

In the literature on scaffolding few studies explicitly examine responsiveness as part of classroom scaffolding. Those that do tend to have a local character in the sense that they concern teacher-pupil or teacher-small group interaction rather than whole-class teaching. Moreover, small units of analysis are used (varying from a single utterance to three-turn sequences or brief interaction fragments), implying that only brief fragments of interaction are investigated to identify responsiveness or contingency (e.g., Van de Pol et al., 2012). Given the interactive nature of scaffolding it is defendable to study a teacher's adaptive behaviour at such micro-levels. As argued before, however, many topics of learning, such as (second) language development, take longer periods of time to pursue (Dixon et al., 2012; Mercer, 2008). In line with our conceptualisation of whole-class scaffolding we think that analysis of both pupils' language development and responsiveness of performed strategies thus also needs to be framed within a larger timescale.

Once we have gained evidence of handover and responsiveness, the question arises how diagnosis occurred, and we analyse this in relation to the other scaffolding characteristics to show how the strategies and characteristics are related. To this end we need fine-grained analysis. Hence our third research question:

3. *How are the performed strategies and characteristics (diagnosis, responsiveness and handover) of whole-class scaffolding related over time?*

As Mercer (2008) noted, few researchers have taken up the challenge to analyse episodes of classroom talk as the aforementioned linked chains of interaction. This lack of research can be explained by the theoretical and methodological challenges posed by the examination of the relationship between time, talk and learning in classrooms (as argued by Littleton, 1999). One challenge is how a class of pupils can be diagnosed: Should all individual pupils be assessed or does the online diagnosis of a sample suffice to get a sense of the group zone of proximal development (Smit et al., in press)? In fact, offline diagnosis (e.g., diagnosing pupil work between lessons) allows a teacher to be responsive to a whole class. Therefore such offline enactment of key characteristics is also included in our analysis.

To understand how pupils' language development unfolds over time in the context of whole-class scaffolding, we need 'story threads' to uncover crucial moments in pupils' performance (during lessons) and in the teacher's performance (during *and* between lessons). A story thread can be seen as a "chain of events" (Nathan & Kim, 2009, p. 113) that illustrates a causal field – a multitude of factors in relation to each other. As an inevitable consequence of the complexity such qualitative analysis brings along, we present only one story thread in this paper, focusing on one aspect of the language to be developed. We could have elaborated multiple story threads, but this one is representative in the sense that it concisely illustrates the layered, distributed and cumulative nature of whole-class scaffolding (another example is presented in Smit et al., in press).

5.2 Methods

5.2.1 Research setting and participants

This study is part of a design-based research project in which three teaching experiments were carried out. The overall aim of the project is to investigate how a teacher in multilingual classrooms can scaffold the development of language needed for mathematical reasoning about line graphs. Design research as envisioned in educational research (Cobb, Confrey, diSessa, Lehrer, & Schauble, 2003) was a suitable methodological approach to accomplish this, as it aims at developing innovative

instructional activities *and* theories. Its highly interventionist nature and cyclic character allowed us to theoretically develop the concept of whole-class scaffolding while at the same time promoting and developing its enactment in classroom situations. In designing lessons, we focused on both mathematical knowledge development and (second) language development. We capitalised on the latter in the following two ways.

In the first place, we used the teaching and learning cycle (e.g., Gibbons, 2002) as a design heuristic. This cycle consists of a series of four stages in which a particular academic text genre needed for a particular school subject is introduced, modelled, jointly practised and eventually individually performed by the pupils. Support is thus withdrawn once pupils gain in proficiency (offline handover to independence). The underlying idea is that pupils need gradual induction into the subject-specific academic language involved in a genre. In our case, the genre to be developed in pupils was the interpretative description of a line graph (Smit, Van Eerde, Kuijpers, & Bakker, submitted for publication; see also Chapter 3 in this thesis). A text in this genre both describes the course of the line graph (e.g., "the graph descends gradually") and interprets its meaning (e.g., "he slowly loses weight"). The genre includes both linguistic features (e.g., the use of subject-specific words) and structure features (e.g., describing each segment of the graph in terms of reality and in terms of the graph's course).

Table 1 Strategies for scaffolding language and examples for each strategy

1. Reformulate pupils' utterances (spoken or written) into more academic wording	[In response to *the graph goes higher and higher up*:] *Yes, the graph does rise steeply.*
2. Ask pupils to be more precise in spoken language or to improve their spoken language	*What do you mean by 'it'?*
3. Repeat correct pupil utterances	*Yes, the graph does descend slowly.*
4. Refer to features of the text type (interpretative description of a line graph)	*Into how many segments can we split the graph?*
5. Use gestures or drawings to support verbal reasoning	E.g., gesturing a horizontal axis when discussing this concept
6. Remind pupils (by gesturing or verbally) to use a designed scaffold (i.e. word list or writing plan) as a supporting material	*Look, the word you are looking for is written down here.*
7. Ask pupils how written text can be produced or improved	*How can we rewrite this in more mathematical language?*

In the second place, we developed a conceptual framework of strategies for scaffolding language (see Table 1). This framework, constructed to both promote and evaluate the teacher's scaffolding performance, was refined in three cycles of design research. Its construction was firstly informed by scaffolding literature, which is for instance

reflected in the potentially responsive nature of all strategies. Secondly, its construction was informed by the empirical data, as these informed us on the extent to which strategies seemed effective for pupils' language development.

For this paper, we only use data from the third teaching experiment, consisting of nine lessons. Because whole-class scaffolding was promoted, classroom interaction predominantly took place in whole-class settings, implying that one-to-one and small group discussions were much less frequent. The experiment was carried out in a combined grade 5-6 class of a suburban primary school (age 10-12). Lessons were given weekly and lasted 60 to 70 minutes each. The number of pupils speaking Dutch as a second language was 19 out of 22, the majority being second or third generation Moroccan and Turkish pupils, who performed rather weakly on a standardised test for language (CITO assessment). The teacher, who had also participated in the two previous teaching experiments, had seventeen years of experience in primary education, partly in multilingual classrooms.

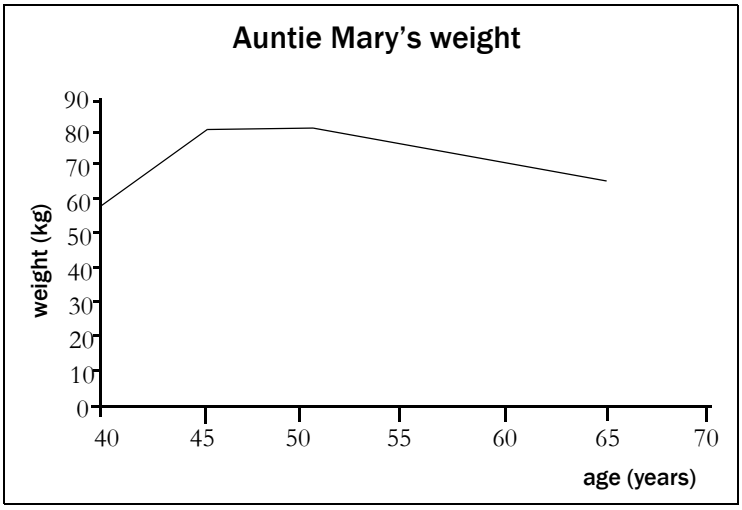
5.2.2 Instruments

We used a pre- and a posttest to determine handover to independence. These tests consisted of respectively nine and eight items and lasted up to 50 minutes (pretest) and 45 minutes (posttest). There were eight days between the last lesson and the posttest. The selection of three test items used for answering the first research question was informed by our choice of the three linguistic key elements needed for reasoning about line graphs, involving various estimated learning burdens (cf. Nation, 2001):

1. A group of graph-related words: horizontal axis, vertical axis and title.
2. A conceptually difficult key word in the domain of line graphs, used to reason about issues of steepness: "gradually".
3. Temporal prepositions: words referring to a particular moment in time, represented by a point in the line graph, for instance *at* 6 o'clock; word combinations referring to a particular period in time, represented by a segment of the line graph, for instance *between* 6 *and* 8 (particularly difficult for second language learners and key to reasoning adequately in the domain of graphs; Chodorow, Gamon, & Tetreault, 2010).

The test items were constructed so as to gain insight into both receptive and productive word knowledge, based on the underlying assumption that both kinds of vocabulary development should be included in tests as they indicate different degrees of proficiency in a second language (Nation, 2001). Receptive knowledge of the graph-related words was measured in a test item in which pupils were asked to mark the horizontal axis, the vertical axis and the title of a line graph. In a subsequent test item pupils were asked to

write down the meaning of a number of subject-specific words. This item was used to investigate pupils' knowledge of "gradually". In the third test item pupils were asked to describe a line graph (without support) for a dual purpose: analysing pupils' productive knowledge of both subject-specific language (including "gradually") and analysing pupils' productive knowledge of temporal prepositions (see Figure 1). These types of productive knowledge are analysed separately (Smit et al., submitted for publication).



Describe how auntie Mary's weight changes and how you can tell from the graph.

Figure 1 Test item for investigating both pupils' productive knowledge of subject-specific language and their productive knowledge of temporal prepositions

5.2.3 Data collection

Apart from the pre- and posttest scores of all 22 pupils, data collection included video and audio recordings of all lessons; all recordings were transcribed verbatim. Furthermore, data collection consisted of pupils' written work, the teacher's weekly written reflections using a reflection format we gave her, audio recordings of video-stimulated recall interviews (SRIs) one of the researchers held with the teacher between lessons (Smit & Van Eerde, 2011), as well as reports on the SRIs written by the researcher. The underlying idea of SRIs is to encourage teachers to think aloud while observing videos of their own lessons, thus stimulating them to relive the lesson (Meijer, Zanting, & Verloop, 2002). At the end of each SRI we discussed the teacher's written reflection, which included questions on her diagnoses, the responsiveness of her strategy performance and her observations of pupils' progress. The characteristics of whole-class scaffolding were also central to these weekly discussions, on the basis of which the teacher formulated scaffolding intentions for the next lesson.

5.2.4 Data analysis

To what extent did handover to independence take place?

To compare pre- and posttest scores on the aforementioned items, we first investigated whether the scores were distributed normally, using the Kolmogorov-Smirnov normality test (in SPSS), to see if we could use the paired-samples t-test. For the first three comparisons, this was not the case ($p < .001$), so we used the non-parametric Wilcoxon's signed rank test. In the last comparison, on temporal prepositions, we could assume normality ($p = .11$) but for better comparison we used Wilcoxon in all cases along with the associated effect sizes (r).

What evidence of responsiveness can be identified?

Our hypothesis was that responsiveness over time should be visible in a shift from high-support to low-support strategies. High-support strategies involve a high level of teacher support and low-support strategies involve a low level of teacher support, thus posing bigger demands on pupils' independence. To examine such a shift a coding scheme with instructions was developed in several rounds (see Tables 2 and 3). The scheme was based on the aforementioned conceptual framework (Table 1), although we slightly regrouped the categories. As a unit of analysis we used the smallest meaningful transcript segment in which the teacher's endeavour to scaffold language could be identified (cf. Rasku-Puttonen et al., 2003). This could be a word, e.g., "horizontal" (when repeating a correct pupil utterance), a sentence, e.g., "What did we call that again?" (when asking for more precise language), or a few sentences which taken together form a strategy for scaffolding language.

Table 2 Coding scheme for identifying high-support (h) and low-support (l) strategies for scaffolding language

Code	Strategy for scaffolding language
RefExt (H)	Reformulating or extending pupils' spoken or written utterances
LingFea (H)	Explicitly referring to or reminding of linguistic features (e.g., subject-specific words or temporal prepositions), or doing so implicitly by referring to or pointing at the word list, or by referring explicitly to supportive gestures
StrucFea (H)	Explicitly referring to or reminding of structure features (e.g., the use of a specific type of language such as mathematical language)
AskImp (L)	Asking pupils to improve language (e.g., asking for more precise language) or to elaborate their utterance
RepCor (L)	Literally repeating correct pupils' utterances or making explicit the good quality of pupils' utterances or gestures
IndPro (L)	Asking for or explicitly encouraging pupils to independently produce spoken or written language

To identify a possible shift, we decided to contrast the earliest and the latest segments in which each of the three aforementioned linguistic key elements was addressed. To this end we needed to balance between two requirements. First, for a contrast we needed a sufficiently large gap between segments to be coded. Second, for measuring the interrater reliability of the coding scheme we needed at least $2n^2$ segments (in our case 72), where n is the number of codes (Cicchetti, 1976). The balance was found in analysing a maximum of two early and two late lessons in which strategies were performed. This resulted in a total number of 80 segments to be coded (see Figure 2 for the distribution of segments over lessons). A second researcher independently coded the 80 segments, resulting in 74 agreements in coding (92.5%) and Cohen's kappa of .90, which indicates a very high interrater reliability. The resulting data were analysed with Pearson's chi-squared test.

Table 3 Example of instructions for coding

Code	Coding instruction for each strategy
RefExt	*1)* Attribute code for reformulations:
	Pupil: The graph goes descending.
	Teacher: Indeed, the graph descends. [correcting grammatical error]
	2) Attribute code for extensions:
	Teacher: So what do I need to do now?
	Pupil: Coordinate system.
	Teacher: Now I am going to draw the coordinate system.

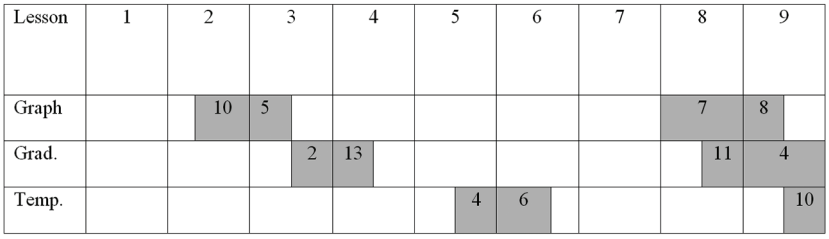


Figure 2 Distribution of segments to be coded: thirty concerning graph-related words (Graph), thirty concerning the use of "gradually"(Grad.) and twenty concerning the use of temporal prepositions (Temp.)

How are the performed strategies and characteristics of whole-class scaffolding related over time?

To answer the third research question we focus on a group of graph-related words that was introduced early in the lesson series (cf. Figure 2): horizontal axis, vertical axis, coordinate system, graph and title. We illustrate the journey of these words towards

independence throughout the lesson series. In chronological order, we identified and coded all segments in the lesson transcripts in which the teacher performed strategies concerning these graph-related words. We read the transcripts around these segments in search of indicators of pupils' progress (or decline) and the teacher's responsiveness (or lack of responsiveness) to pupils. Subsequently, we identified all teacher comments in relation to these graph-related words during the SRIs that could be interpreted as diagnosis, or an intention to responsiveness or handover to independence. From the chronological list of both transcript fragments and teacher comments we selected those elements that signified change or improvement (there were very few examples of decline). These elements form the basis for the story thread.

5.3 Results

5.3.1 Research question 1: handover to independence

The comparisons of pre- and posttest scores all yielded statistically significant differences (see Table 4). The effect sizes are large ($r = z/\sqrt{N} = .5$ is considered large, N is the number of measurements, 2*22=44). For readers who are used to effect sizes measured with Cohen's *d*, we also report $d = 1.13$ on temporal prepositions (0.8 is considered large). This suggests that pupils have become much more independent on these linguistic aspects of the genre of reasoning about line graphs. Thus handover to independence occurred to a large extent.

Table 4 Pre- and posttest scores and results of Wilcoxon signed rank test and effect sizes

	Topic	Pretest Mean (SD)	Posttest Mean (SD)	Max score	*z* value	Effect sizes (*r*)	Ranks (positive, tie, negative)	*p*
1	Graph-related words (total)	0.59 (0.73)	2.36 (1.09)	3	3.70	.79	17 +; 4 ties; 1 -	<.001
	- title	0.50	0.91	1				
	- horizontal axis	0.045	0.73	1				
	- vertical axis	0.045	0.73	1				
2	Gradually	0.00	0.73	1	4.00	.85	16 +; 6 ties; 0 -	<.001
3a	Subject-specific	0.16 (0.47)	2.68 (1.39)	4	3.87	.83	19 +; 3 ties; 0 -	<.001
3b	Temporal prepositions	2.20 (0.55)	3.84 (1.51)	6	3.53	.53	16+; 6 ties; 0 -	<.001

5.3.2 Research question 2: responsiveness

Table 5 shows the frequencies of strategies performed per group. The frequencies suggest a shift from high-support to low-support strategies. This shift is indeed statistically significant, $\chi^2 (1, N = 80) = 22.75$, $p < .001$. This shows evidence of the

teacher's responsiveness to pupils' levels of language proficiency in her enactment of language promoting strategies.

Table 5 Frequencies of high- and low-support strategies

	First period	Last period	Total
High-support strategies	34	13	47
Low-support strategies	6	27	33
Total	40	40	80

5.3.3 Research question 3: story thread about graph-related words

Having given evidence of handover to independence and responsiveness by means of quantitative data from the beginning and end of the lesson series, we now use qualitative data as the basis for a connecting story thread that shows how the teacher strategies are linked to the scaffolding characteristics of diagnosis, responsiveness and handover. We use abbreviations to refer to lessons and strategies; for example 'L2 LingFea' means lesson 2, and performance of the LingFea strategy (see Table 2) concerning linguistic features.

In lesson 2, the teacher introduces the term "horizontal axis":

> What is "horizontal axis"? Is that this one (moves her hand vertically) or is this one (moves her hand horizontally). What is the horizon? I always remind myself: what is the horizon. Who knows? The horizon. Think of the sea [L2 LingFea].

The teacher performs the high-support LingFea strategy a few more times, i.e., she centralises the newly introduced concept by referring to phenomena pupils know (the horizon at sunset). She also introduces the related words "vertical axis" and "coordinate system". In line with theories on second language development (Dixon et al., 2012) the teacher returns to the introduced words several times. We consider these instances online responsive to pupils' linguistic levels: only one pupil (out of 22) demonstrated receptive word knowledge of horizontal axis and vertical axis in the pretest (offline diagnosis).

In the second half of lesson 2 the teacher starts extending pupils' utterances by using the graph-related words in full sentences or by adding the definite article (both RefExt strategy). The definite article is particularly difficult for second language learners of Dutch because this language uses two different articles (one for masculine and feminine words and one for neutral words). Both the extension and reformulation of pupils' utterances can be considered as online responsively performed strategies in the case of emerging word knowledge.

The teacher also encourages pupils to use the word list on the wall as supportive material (LingFea strategy). This list is used both to write down newly introduced subject-specific words, and to return to these words (verbally or by gesturing) when required in whole-class mathematics discussions, as the following fragment illustrates.

Teacher	Step one. What am I going to do?
Bela	At the coordinate system…
Teacher	Very good, isn't it? You may not have seen it, but I saw her eyes. Rrrts went her eyes (teacher points from Bela to the word list on the wall) [L2 LingFea]. Coordinate system. That is very smart, because it takes some time for that word to sink in. (…) Does it matter which one [axis] I draw first? No, but we want to practise using those words.

The fragment also exemplifies how the teacher establishes a norm concerning the need to employ subject-specific words for discussing mathematical content. Establishing such norms contributes to pupils' awareness of the need to learn subject-specific language for participating in mathematical discussions. In subsequent interaction fragments in lesson 2 several pupils do start using the graph-related words (supported by the word list). One of the few pupils whose native language is Dutch, is the first one to include horizontal axis in a full sentence: "Then you will, you write centimetres along the horizontal axis."

In the SRI after lesson 2 the teacher states from memory: "I presume five pupils to have added the concept 'horizontal axis' and 'vertical axis' to their vocabulary." We infer online diagnosis from this statement as it indicates that the teacher has tacitly diagnosed pupils' word knowledge. During this SRI the teacher expresses the presumption that pupils will need less extensive linguistic support in the next lesson, which indicates the start of a process of handover: "Next time only gesturing will be sufficient support, or at least I will spend fewer words explaining the meaning [of horizontal axis]."

What struck us from the analysis was the importance of intentions as connecting diagnosis to future responsiveness or handover. The first crucial intention, expressed in the same SRI, was to support pupils in actively using the targeted language, based on the online diagnosis of pupils' language use:

> And for Abdul…he really speaks what I call "street language". I just need to encourage him to use this [subject-specific] language correctly a few times. He needs to experience what it is to talk like this; he needs to experience that he can actually produce this kind of language.

The second intention, also based on a tacit online diagnosis, concerns the following general aspects: "I want to focus more on pupils completing their sentences, as well as on those pupils who haven't yet verbally contributed."

During lesson 3 the teacher returns to the previously introduced words and notices many pupils are now able to gesture in the right directions of both axes. She makes this progression explicit to pupils (online handover; RepCor strategy):

Teacher	What was it again, "horizontal"?
Abdul	(Abdul moves his hands to and fro in horizontal direction)
Teacher	You go like this already! (Teacher makes the same movement as Abdul.) Yes. Good, isn't it? Indeed. That was horizontal [L3 RepCor].

During the SRI after lesson 3 the teacher articulates this process as follows: "It goes exactly as I predicted earlier: pupils are taking over the gesture for horizontal axis and less words are needed to explain the concept." The teacher seems to have internalized the promoted new way of teaching, as she perceives such statements as on-the-spot decisions and thoughts of her own. The following statement out of the same SRI also indicates a process of handing over, as the teacher infers from her tacit online diagnoses: "Horizontal axis and vertical axis are starting to sink in, but these concepts are not yet known to everybody, so more practice is needed here."

During lesson four the teacher again pays explicit attention to the concept of horizontal axis (LingFea strategy) due to one pupil mixing up the axes. Soon after that a Dutch language learning pupil, Abdul, productively uses the concept by himself in an adequate way. His development from gesturing (lesson 3) to producing language (lesson 4) indicates increased linguistic independence:

Teacher	What did we do next, Abdul?
Abdul	Weeks at, the weeks along, writing the weeks along the horizontal axis.
Teacher	Indeed [L4 RepCor].
Abdul	And the time.
Teacher	We have written time in weeks along the horizontal axis [L4 RefExt]. And?
Abdul	And along the vertical axis we had to write centimetres.

Later in lesson 4 the teacher asks another pupil to independently produce a sentence (IndPro strategy). This is the first time she uses this low-support strategy (see following fragment). We consider this interactively responsive to the spontaneous word use by Abdul earlier in the same lesson.

Yassin	Horizontal axis (points to the horizontal axis).
Teacher	Can you put that in a sentence [L4 IndPro]?

During the SRI after lesson 4 the teacher does seem to have diagnosed pupils' progressing word knowledge: "Pupils' knowledge of words has increased, I concluded from the round I conducted." This online diagnosis is confirmed by the teacher's offline diagnosis based on pupils' linguistic levels in written work: for example, 16 out of 22 pupils have acquired receptive word knowledge of horizontal axis. As a consequence, we decide to focus our attention on other words and linguistic aspects still in need of scaffolding.

Table 6 Frequencies of strategies for the scaffolding of graph-related words performed in each lesson

Lesson	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Strategy								
RefExt	3	1	2	2	2		2	
LingFea	6	7	7	2		1	3	1
StrucFea								
AskImp			1	8	2	2	1	2
RepCor	1	2	4	4		2	5	5
IndPro				1			2	
Total	10	11	14	17	4	5	13	8

Note: The StrucFea strategy was not enacted for this particular linguistic key element.

Despite our shift of attention, pupils' language development concerning the graph-related words continues to evolve: spontaneous use of the concepts happens more frequently and pupils more often use these concepts in longer phrases. In line with this development, Table 6 shows a relative increase of low-support strategies (RepCor, AskImp, IndPro) and a decrease of high-support strategies (LingFea, RefExt). Towards the end of the lesson series, the teacher also refers to pupils' gained independency several times, as for instance in: "For that we know proper mathematical language" (L7 AskImp). The following fragment from lesson 7 exemplifies this stage in the process of handover, concerning both pupils' and the teacher's development.

Semi	He weighs 85 kilograms.
Teacher	He weighs 85 kilograms [L7 RepCor]. OK. Hamid, how can he tell?
Hamid	From the vertical axis.
Teacher	From the vertical axis, yes [L7 RepCor]. Along the vertical axis we see the data on Uncle Kees's weight [L7 RefExt]. And what informs him about his age? Youness.
Youness	Down below. (…)
Teacher	And down below, for that we know proper mathematical language [L7 AskImp]. Oussana.
Oussana	Horizontal axis.

Teacher	Now put that in a sentence [L7 IndPro]. That's just a word, "horizontal axis" is just a word on its own like that.
Oussana	Along the horizontal axis it says age in years.
Teacher	That's a beautiful sentence, isn't it [L7 RepCor]?

The following remark during the SRI after lesson 7 points to online diagnosis, and to adjusting an earlier made diagnosis: "I hadn't expected they would speak in full sentences so well."

With this story thread we hope to have given an impression of the qualitative relationships between teacher strategies and scaffolding characteristics over time, hence the texture of whole-class scaffolding. First, the story thread points to how diagnosis is related to responsively using strategies: They are connected by intentions. Secondly, the story thread exemplifies possible relationships between online and offline diagnosis: confirmation or adjustment. Confirmation was at stake when offline diagnosis endorsed what the teacher had diagnosed online on the basis of a small sample of pupils. Adjustment was necessary when a new diagnosis refuted one made earlier. A third point we want to make is that this story thread, in particular Table 6, confirms a relationship that we already found in the answer to research question 2: The shift from high- to low-support strategies indicates responsiveness over time. In sum, the cumulative online enactment (e.g., responsive performance of strategies) and offline enactment (e.g., diagnosis) of key characteristics over time eventually led to handover to independence. This story thread thus illustrates the layered, distributed and cumulative nature of whole-class scaffolding.

5.4 Discussion

The present study aimed to investigate whether the enactment of strategies intended to scaffold the development of a subject-specific genre did lead to whole-class scaffolding as identifiable by its key characteristics (handover, responsiveness and diagnosis). We employed a long-term conceptualisation and analysis of whole-class scaffolding. In answer to the first research question, we can conclude that pupils have become significantly more independent on the measured linguistic key elements of the genre needed for reasoning about line graphs. This points to a long-term process of handover to independence. The second research question's answer can be found in a statistically significant shift from high-support to low-support strategies. This shift indicates that the teacher adjusted her performance of strategies to pupils' levels of language proficiency. Her strategy use was therefore responsive over the long-term. In answer to the third research question, we can conclude that performed strategies, the three key

characteristics of whole-class scaffolding (diagnosis, responsiveness, handover) and pupils' progress appeared to be closely linked over time. These answers provide empirical evidence of the realisation of whole-class scaffolding by means of strategies for promoting pupils' language development.

Although several researchers have indicated the importance of linking talk and learning over time (e.g., Mercer, 2008), such long-term analyses have rarely been conducted in scaffolding research (an exception is Rasku-Puttonen et al., 2003). We employed mixed methods to benefit from the strengths of both approaches and to generate evidence of different kinds (cf. Mercer, 2010). The quantitative methods used allowed for contrasting numerical comparisons between pupils' proficiency levels as well as between teacher strategies performed in early and late lessons. To give meaning to these quantitative results, a qualitative analysis provided a detailed examination of what the process of whole-class scaffolding actually looked like, linking strategies, key characteristics and pupils' progress over time. Hence the methodological significance of this study lies in yielding methods for analysing whole-class scaffolding that is intended to foster long-term learning processes. We presume that such methods can be used for analysing whole-class scaffolding in other domains as well because they do not seem to depend on domain-specific knowledge.

A first limitation concerns the rather confined measurement of handover to independence. Second language theorists, for instance, may suggest to include pupils' ability to connect newly acquired words (e.g., "gradually") to words already present in the learner's lexicon in the analysis (cf. Ellis, 1997). From a sociocultural perspective one may argue for measuring independence in a broader sense (cf. Lockhorst, Wubbels, & Van Oers, 2010), for instance as a manifestation of an emerging language community. Research on such a language community could include analysis of classroom discourse: How and to what extent does pupils' use of subject-specific language evolve over time? Furthermore, it could include measuring pupils' own initiative in whole-class settings, or pupils' scaffolding of each other (cf., Fernandez, Wegerif, Mercer, & Rojas-Drummond, 2001).

A second limitation concerns the representativeness of our story thread. The story thread provided an answer to the third research question in that it illustrated how performed strategies were related to online and offline enactment of key characteristics over time, in this particular study. However, further research is needed to verify whether the relationship patterns found here (e.g., between online and offline diagnosis) also occur in other whole-class scaffolding situations. Such research can also deepen our understanding of the layered, distributed and cumulative nature of whole-class scaffolding.

A question that may rise is whether our study provides a warrant for suggesting that teacher strategies have indeed been the main cause of pupils' increased independence. Inevitably, there have been more factors at stake that may have contributed to pupils' progress (e.g., the teacher providing occasional individual support). Instead of asserting specific causal relations between the enactment of individual strategies and effects on pupils' development, we prefer to view the evidence of whole-class scaffolding as pointing to a causal field. We think it is highly plausible that strategies performed in our teaching experiment have been vital in this causal field. A strong indication is pupils' better appropriation of genre elements after the teacher's enactment of strategies, as visible in the story thread. As Jadallah et al. (2011, p. 226) argue, such evidence is not decisive but the likelihood that pupils would say what they say is "vanishingly small" without the teacher's influence.

In sum, we think we have provided empirical evidence for the long-term realisation of whole-class scaffolding as a result of performing particular strategies. Because these are not domain-specific, we think that they can also be applied for the whole-class scaffolding of other subject-specific genres required throughout the curriculum.

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Chapter 6

General conclusion and discussion

General conclusion and discussion

…the quality of teachers in the classroom is the single most significant influence on students who are educationally at risk. (Love, 2009, p. 542)

6.1 Main findings

Against the background of increasing linguistic diversity in classrooms worldwide, we aimed to provide scientifically grounded insight into how language-oriented mathematics education can be designed, enacted and evaluated. In a general sense, this study addressed the challenge of teaching in linguistically diverse classrooms – a challenge that has up to now not been sufficiently met. More specifically, we aimed to contribute to better educational and societal opportunities for multilingual pupils by focusing on their language development required for mathematical learning. The study conducted can therefore be considered as an endeavour in the field of content-based second language teaching. It also puts Hans Freudenthal's adage "mathematics for all" (1991, p. 178), which underlies his work on realistic mathematics education, in a contemporary light. We addressed the following main research question:

> *How can teachers in multilingual primary classrooms scaffold pupils' language required for mathematical learning?*

Chapter 2 addresses the question of how a teacher participating in dual design research learned to scaffold multilingual pupils' language development required for mathematical learning. Dual design research is a special case of design research that aims to promote and trace the development not only of the *pupils'* but also of the *teacher's* learning. We addressed the following subquestions:

> *2.1 What can a teacher participating in dual design research learn in terms of scaffolding pupils' development of the language required for mathematical learning?*
>
> *2.2 To what characteristics of dual design research can the participating teacher's learning process be attributed?*

In response to research question 2.1, we concluded that the teacher's self-reported and derived learning pointed at changes in knowledge and beliefs, changes in practice and intentions for practice. Concerning the category of knowledge and beliefs, the teacher became aware of the difficulty and necessity of adequately performing scaffolding strategies in multilingual classrooms and of multilingual pupils' hidden linguistic incompetence. She also increasingly acknowledged the need for multilingual pupils to participate actively in classroom discourse and produce subject-specific language. Her intentions became richer as well: At first her intentions were only related to formulating

more precisely, but from the second design cycle onwards the variety of reported intentions for practice increased. For example, she reported the intention to better integrate language in mathematics lessons. In response to research question 2.2, we concluded that the teacher's learning process could be attributed to the characteristics of dual design research, that is its cyclic and interventionist character, the continuous process of prediction and reflection that lies at its heart, and the process of co-designing complemented with the stimulated recall interviews. In particular the stimulated recall interviews were of crucial importance for raising the teacher's awareness. We concluded that dual design research seems a fruitful methodological approach to promote and investigate the teacher's learning processes, especially at the start of exploratory research.

In **Chapter 3**, we introduce the notion of *pedagogical genre*, which is a genre that has been deliberately designed as a learning goal. It is captured in terms of structure and linguistic features with examples as an instructional aid for teachers to focus their and pupils' attention on what matters most in talking or writing about a particular domain. We addressed two research questions to evaluate whether pupils indeed developed proficiency in the pedagogical genre of *interpretative description of a line graph*:

3.1 To what extent did pupils make progress in deploying the pedagogical genre?

3.2 How can we characterise the development of pupils' genre proficiency?

In answer to research question 3.1, we concluded that pupils progressed in deploying the genre to a large extent: The average score for pupils' writing in the pedagogical genre in the posttest was 2.89 points higher than their average score in the pretest, measured on a 10-point scale. This difference was statistically significant ($t = 8.37$; $df = 21$; $p < .001$), with an effect size of $d = 2.20$, which can be considered very large (Cohen, 1988). In answer to research question 3.2, we concluded that the four case-study pupils showed gradual development with some falling back over the course of the lessons. By and large their development was in line with what we had conjectured in the HLTs (hypothetical learning trajectories). For example, they all showed progress in the use of subject-specific language (e.g., *rise*, *descend*). Closer examination of individual learning processes revealed where the observed learning slightly diverged from the hypothesised learning. For none of the four case-study pupils providing graph descriptions in terms of reality (e.g., "slowly loses weight") and in terms of the course of the graph (e.g., "descends gradually") had become a habit. Cases where hypothetical and observed learning differed indicate that even more time and attention should be directed towards supporting multilingual pupils' development of the required pedagogical genre. To us, this reinforces the need for a linguistic turn we propose for educational design.

The aim of **Chapter 4** is to theoretically and empirically ground a conceptualisation of whole-class scaffolding that stays as close as possible to the spirit of the origin of the scaffolding concept, but that also leaves room for features not salient in one-to-one interaction. Drawing an analogy with Vygotsky's (1978) concept of ZPD (zone of proximal development), we first argued why the extension from one-to-one (teacher-pupil) to whole-class settings was justified. In line with the scaffolding literature, we subsequently distinguished three key characteristics of whole-class scaffolding: diagnosis, responsiveness and handover to independence. So far, scaffolding has mainly been conceptualised as happening in live dialogue only. However, our study pointed to the fact that parts of the scaffolding process can occur outside classroom interaction. Diagnoses can namely also be made outside lessons, for instance by analysing pupils' written work; responsiveness can also be realised in adapting instructional activities in between lessons; and handover to independence can also be fostered in the design of lessons (in our case by employing the teaching and learning cycle as a design heuristic to promote proficiency in the pedagogical genre). We therefore metaphorically distinguish between *online* and *offline* enactment of key characteristics of whole-class scaffolding; respectively *during* or *outside* whole-class interaction. Our empirical findings also point to more features of whole-class scaffolding that capture its nature. In addition to this *layered* nature (online vs. offline), whole-class scaffolding is often *distributed* over time. Finally, whole-class scaffolding is *cumulative*, with pupils' independence emerging as the cumulative effect of many diagnostic and responsive actions over time. We suggest these three features are at the core of whole-class scaffolding that is deliberately employed to foster long-term learning processes. Furthermore, we conjecture that the features of whole-class scaffolding that we identified may well hold for one-to-one scaffolding that goes beyond a brief interaction between a teacher and a pupil. As such our conceptualisation enriches the understanding of scaffolding more broadly.

The aim of **Chapter 5** is to investigate whether the enactment of strategies intended to scaffold the development of subject-specific language in a multilingual upper primary mathematics classroom indeed led to whole-class scaffolding as identifiable by its key characteristics (diagnosis, responsiveness and handover to independence), taking into account the long-term nature of whole-class scaffolding. To fulfil this aim we addressed three research questions in response to the aforementioned methodological challenges.

5.1 To what extent did handover to independence take place?

5.2 What evidence of responsiveness can be identified in the teacher's enactment of strategies for promoting language development?

5.3 How are the performed strategies and characteristics (diagnosis, responsiveness and handover) of whole-class scaffolding related over time?

In response to research question 5.1 we concluded that comparison of pupils' pre- and posttest scores on three linguistic key elements all yielded statistically significant differences with large effect sizes, thus confirming handover to independence. We can further state that a statistically significant shift from high-support to low-support teacher strategies revealed the teacher's responsiveness to pupils' linguistic levels over nine lessons. This answers research question 5.2. In response to research question 5.3 we provided a story thread that showed the interrelatedness of performed strategies and scaffolding characteristics (e.g., diagnosis) over time.

All in all, our study showed how teachers in multilingual primary classrooms can scaffold pupils' language required for mathematical learning. The participating teacher used instructional activities that we deliberately designed so as to promote pupils' reasoning about line graphs. She constantly used a repertoire of strategies to support pupils' proficiency in the pedagogical genre of interpreting and describing line graphs. The empirical analyses indicate that the classroom interaction as shaped by the teacher could indeed be characterised as whole-class scaffolding: The teacher diagnosed and was responsive to pupils' written work and oral utterances, and she handed over to independence. Learning gains were statistically significant with large to very large effect sizes. Our study thus provides evidence of how language-oriented mathematics education can be designed, enacted and evaluated.

6.2 Discussion

6.2.1 Contributions

As the motto for Chapter 1, we chose a statement by Edwards and Mercer (1987, p. 101): "It is essentially in the discourse between teacher and pupils that education is done, or fails to be done." With this motto, we wanted to stress the crucial importance of the teacher for pupils' educational success (cf. Biesta, 2012). In the motto of this final chapter we emphasised that multilingual pupils rely on the teacher to an even larger extent than their native peers. We now want to specify the contributions of this thesis. The first two have a theoretical nature as they concern two empirically grounded notions that this study yielded. The third one is a methodological contribution related to teachers' professional development in the context of design research.

First, we came up with the notion of *pedagogical genre*, which was the result of deliberately moulding a genre for the pedagogical purpose of learning to reason about line graphs. The design-aspect related to this notion of pedagogical genre can be considered a theoretical innovation, as genres have so far only been studied as phenomena already present in society and school. Furthermore, the idea of designing language use, in

particular in written form, has so far been hardly investigated in mathematics education. The notion of pedagogical genre also contributes to the field of content-based second language teaching. In Chapter 1 we described two well-known models within this content-based approach: the model of sheltered instruction and the relatively recent model of the teaching and learning cycle. We have argued that the teaching and learning cycle can also be applied to promote pupils' genre proficiency in genres required for subject-specific learning; in our case the pedagogical genre of interpretative description of a line graph.

Secondly, we conceptualised *whole-class scaffolding*, a concept used so far in diverging and often loose ways. In conceptualising, we formulated three key characteristics of whole-class scaffolding that are in line with the literature: diagnosis, responsiveness and handover to independence. The main theoretical contributions of the whole-class scaffolding conceptualisation to the field of scaffolding research concern 1) the theoretical justification of whole-class scaffolding, 2) the distinction between *online* and *offline* enactment of key characteristics and 3) the identification of its layered, distributed and cumulative nature. Our conceptualisation also contributes to the broader sociocultural theory from which it stems. For our theoretical justification, we closely examined the interpretations and applications of the underlying notion of ZPD and pointed out that scaffolding, in line with ZPD, should not necessarily be individually instantiated. Furthermore, the long-term dimension of many learning processes, as often emphasised in socioculturally framed literature (e.g., Mercer, 2008), was included in the conceptualisation of whole-class scaffolding (Chapter 4). Moreover, we have responded to consequential methodological challenges by providing empirical evidence of the long-term realisation of whole-class scaffolding (Chapter 5), including the long-term responsive enactment of scaffolding strategies upon the class as a whole. Generally speaking, this study has yielded tools and accompanying insights for teachers' fulfilment of their role as a *more knowledgeable other* in classroom interaction that is directed towards supporting pupils' language development.

Thirdly, this study has elaborated the methodological approach of dual design research. To start with, it has yielded written pre- and postinterview schemes serving to *trace* a teacher's learning processes. In addition, these schemes provide insights into those aspects of a learning environment to which a teacher attributes his or her learning process. We presume that these schemes may well be applicable in future design research. More importantly, is has furthered our knowledge on instruments that can help *promote* teachers' learning in the context of dual design research. The research instrument of the HLT, typically employed in design research to promote pupils' learning, also functioned as an instrument to promote the teacher's learning. The HLT

formed the core of the co-designing process in that we involved the teacher in the formulation of each HLT and also in the evaluation of each lesson on the basis of the HLT. A second research instrument used to promote the teacher's learning in the context of dual design research formed schemes for reflection-promoting stimulated recall interviews (cf. Meijer, Zanting, & Verloop, 2002). Our study pointed out that this instrument can well foster teachers' awareness, for instance concerning multilingual pupils' hidden language problems as well as concerning the need to centralise mathematics and language in an integrated way (e.g., by using an *expanding word list* during teaching). As very little was known about what and how a teacher can learn from participating in design research up to now, we consider these yields a methodological contribution of this study.

6.2.2 Countervoices and rebuttals

Over the past years we have had several questions after presentations and in discussions with colleagues. From these we have distilled the most prominent countervoices. These concern our conceptualisation of whole-class scaffolding as well as the developed repertoire of strategies for scaffolding language. In the following we engage in a dialogue with readers who represent these countervoices.

One may wonder why we attribute the notion of scaffolding to teaching and learning processes that seemingly have a different nature from what Wood, Bruner and Ross (1976) referred to as scaffolding in their initial publication on adults' supportive role in dyadic adult-child interaction in the context of problem-solving. Indeed, in our conceptualisation of whole-class scaffolding we extended the notion of scaffolding in several ways: by employing it for support given to the class as a whole, by including the long-term dimension of learning, and by including the enactment of diagnosis, responsiveness and handover *outside* classroom interaction (e.g., diagnosing on the basis of pupils' written work). Some scholars would argue that scaffolding can only occur in live interaction and that everything taking place outside interaction by definition cannot be called scaffolding.

In rebuttal, we stress that concepts unavoidably *travel* across disciplines and throughout time, and that this is part of their usefulness and theory-enriching power provided that the essence of a concept remains intact (Bal, 2009). The concept of scaffolding has undergone conceptual extensions ever since the original publication and this can be related to the emergence of a broader and richer picture of Vygotsky's developmental theory in the 1980s, to which the scaffolding concept was increasingly linked (Minick, Stone, & Forman, 1993; Stone, 1998). Where the original characterisation was pragmatically directed towards instilling new skills and understanding in the child, it was

much less concerned with the interactional mechanisms which underlie this process (as noted by Stone, 1993). The adaptive mechanism of responsiveness (or contingency), for example, increasingly received attention in the literature (Van de Pol, Volman, & Beishuizen, 2010), whereas the original publication (Wood, Bruner, & Ross, 1976) did not explicitly include responsiveness in the characterisation of scaffolding. Our broadening of the scaffolding concept to application in a larger group in fact resonates well with the theory from which it stems: learning to talk *as a mathematician* by participating in *social interaction* guided by a *more knowledgeable other* who offers *responsive* help *over time* is well in line with Vygotsky's key ideas underlying sociocultural theory. We further argue that broadening the scaffolding concept to whole-class settings is also substantiated by the assumption that the ZPD can be established for the class as a whole (Wertsch, 1991). Admittedly, extending the concept to application in whole-class settings raises new challenges, for example how to offer responsive help upon a class as a whole. We have responded to conceptual challenges by proposing a conceptualisation of whole-class scaffolding that remains close to the origin of the scaffolding concept, namely by including key characteristics that are in line with the scaffolding literature (Chapter 4). Our conceptualisation of whole-class scaffolding captures its interactional and responsive nature, but at a larger time scale: A teacher's response may come in a next lesson, after he or she has diagnosed pupils' written work in between two lessons; and adaptive support may be materialised in the revision of instructional activities rather than purely in what is said or done immediately after a pupil utterance. In other words, we allow for activities that are not live interaction to be part of the scaffolding process. We thus propose that the connotation of the scaffolding concept to live interaction is only an artefact of situations in which this phenomenon was initially studied rather than essentially belonging to the concept.

A further discussion point concerns the development of the repertoire of strategies for scaffolding language: One may wonder to what extent this repertoire is distinctive from other categorisations and frameworks of strategies. In response, we note that many frameworks of strategies that have been developed to support classroom interaction focus either on pupils' joint construction of content knowledge (e.g., Alexander, 2008; Mercer, 2000), or on skills to comprehend content, such as Palincsar and Brown's (1984) reciprocal teaching strategies for supporting reading comprehension. Literature that does include strategies or frameworks intended to scaffold language development (e.g., Gibbons, 2002; Walqui, 2006) has so far not employed a precise conceptualisation of scaffolding to empirically test whether classroom interaction fulfilled particular key characteristics. Evidence of the enactment of whole-class scaffolding (by performing particular strategies) related to a clear conceptualisation of scaffolding in terms of key characteristics and features (as described in Chapter 5) has thus hardly been provided in

research on scaffolding up to now (exceptions are Mercer & Fisher, 1992; Rasku-Puttonen, Eteläpelto, Arvaja, & Häkkinen, 2003). Of course, there are other valuable approaches to supporting pupils' language development required for subject-specific learning. An example includes Temple and Doerr's (2012) instructional strategies aimed at developing fluency in the mathematical register. We are not suggesting that scaffolding is the only or most suitable approach for supporting language development. Rather, we view scaffolding as unique in capturing both the teacher's performance (fostering handover) and pupils' learning processes (developing independence). What we do stress is that the assertion of strategies being *scaffolding strategies* should be theoretically justified, for instance by drawing on a clear conceptualisation of scaffolding in terms of key characteristics (Chapter 4), and empirically tested (Chapter 5).

6.2.3 Limitations

A first limitation of the study reported here concerns the participation of only one external teacher, teaching only one domain within mathematics (line graphs) in only three classes (in three different schools). The limited number of participants in this study makes statistical generalisation impossible. Our aim, however, was not to provide evidence of this kind. Frick (1998) convincingly argued that most psychological experiments do not generalise from random samples either. Rather, they reveal propensities and processes. Similarly, we rather aimed to gain insight into processes of teaching and learning and into the development of instructional theory. This is the kind of research most needed if we are to improve education in multilingual classrooms (Elbers, 2012). We argue that the results in this research project in fact do surpass the local context in which it was carried out. The two theoretical notions that it yielded (whole-class scaffolding and pedagogical genre) transcend the context of the classrooms in which the experiments were carried out, and they are also applicable beyond the context of mathematics education. As such the type of generalisation accomplished in this project was theoretical (Yin, 2009).

It may further be argued that without control groups it is hard to judge the learning gains of the pupils reported in this thesis. Indeed, we have not provided proof of pupils' learning by showing their gains compared to a control group. However, we think in line with Biesta (2010) that there are more ways than experimental research to generate valid scientific knowledge about what works, and that many claims about evidence in education are in fact problematic. For example, the idea of isolation can be criticised for denying that pupils' gained knowledge is always influenced by contextual factors, which inherently questions the predictive potentials of statements about "what works". Design researchers, alternatively, do not aim to exclude influencing outside factors, but deliberately include a process of predicting, designing, enacting and reflecting in the

experimental phase. Rather than aiming to find out if participation of pupils in a particular intervention results in particular anticipated behaviours, design researchers aim "to understand the relation between the pupils' participation and the conjectured mental activities" (Gravemeijer & Cobb, 2006, p. 25). This explains why it would be hard to exclude the language-oriented nature (pedagogical genre, scaffolding strategies etc.) from the lesson design without fundamentally changing it. Any comparison with a control group would in our view invoke a comparison of apples and oranges. In addition, we note that anyone who knows the context of the results will recognise the vital role of the teacher's scaffolding strategies for pupils' language development. Although more factors may have contributed to pupils' learning (e.g., the teacher providing occasional individual support), we stress that it is highly implausible that pupils' language development would have taken place the way it did without the teacher's enactment of whole-class scaffolding. The study has yielded strong indications underpinning this view, for instance pupils' better performance in the pedagogical genre after the teacher's enactment of strategies for scaffolding language (cf. the story thread in Chapter 5). Moreover, the effect sizes are very large, so it is worth investing in further refinement of the approach.

6.2.4 Future research

This study also leaves issues to be investigated in future research. Although many are worth mentioning, we confine this section to those issues that seem most crucial to us.

As this study has only yielded one pedagogical genre for one particular domain of mathematics, we recommend designing pedagogical genres for other domains too, both inside and outside mathematics. In this way, we hope that their nature can be better specified, and that this can advance our understanding of ways in which pedagogical genres can become part of and inform educational design. Multiple cycles of conjecture and implementation are typically required to decide if a new theoretical construct can be characterised as an ontological innovation. Thus future research will have to show whether the construct of pedagogical genres can inform educational design at a larger scale and whether it has the theoretical potential of providing a lens through which previously implicit aspects of design can be made explicit.

In this study we have primarily focused on the role of the teacher in realising language-oriented mathematics education. One of the yields of the design process forms the repertoire of strategies for scaffolding language that was developed in several design cycles. This repertoire positions the teacher at the centre of the scaffolding process. After all, we aimed for the teacher to support pupils' language development by enacting these strategies. This does not mean that we consider scaffolding to be a solely teacher-focused

activity. In line with several scholars, we do feel that the scaffolding process should be meaningful for pupils (e.g., Alexander, 2008; Kinginger, 2002; Rasku-Puttonen, Eteläpelto, Arvaja, & Häkkinen, 2003; Rogoff, 1990). Only if pupils know what the agenda underlying the scaffolding of language is, will the scaffolding process itself make sense to them. In the experimental lessons within this research project, we therefore encouraged the teacher to question not only what was pursued but also why (e.g., "why are we actually trying to formulate precisely?"). A recommendation for future research is to further investigate this role of metalanguage (language about language) during the process of whole-class scaffolding. We suppose that metalanguage may be crucial for pupils' sense-making (cf. Van Oers, 1996) of the scaffolding process at stake – hence for pupils' personal significance attached to the development of genres required for learning at school. In line with Love's (2009) findings, we think that teachers do not naturally dispose of such metalinguistic skills: Our participating teacher only did to a small extent, despite her experience and extensive preparation to this study. Thus, future research also needs to look into fostering teachers' metalinguistic proficiency so as to give pupils a sense of why they pay attention to language in a mathematics or other subject matter lesson.

A remaining issue is the need to further investigate the possibilities of dual design research and other approaches to promote teacher learning. Chapter 2 provided insights into mechanisms underlying the teacher's professional development (e.g., reflecting on lessons in stimulated recall interviews). As mentioned in Chapter 2, a 'new' teacher (in another multilingual upper primary mathematics class) was involved in the third experiment and we supported her expertise development in similar, but less labour-intensive and less time-consuming ways. For example, we did conduct stimulated recall interviews, but only made use of those types of questions that seemed to have the most awareness-raising and thought-provoking nature (e.g., "Do you remember what your intention was upon enactment of this strategy?"). Although we have not analysed this new teacher's professional development in the context of dual design research in detail, our lesson observations indicated that the adopted dual design research approach did indeed support the new teacher in realising whole-class scaffolding. Future research is to continue such upscaling by further investigating the ways in which different approaches can promote larger-scale professional development.

6.2.5 Implications

The teaching experiments were conducted in the Dutch context and were designed following principles of the theory of RME (realistic mathematics education). As mentioned in Chapter 1, one of the tenets defined for RME is phenomenological exploration (Treffers, 1987). This concerns the exploration of rich and meaningful contexts or phenomena to develop intuitive notions that can be the basis for

mathematical concept formation. We argue that this phenomenological exploration should include a *linguistic exploration*. After all, if the exploration of contexts requires pupils' active contributions in whole-class interaction, this involves context-bound language. An example from this study illustrates that language development can directly relate to the development of mathematical knowledge. For distinguishing between moments in time (points in the graph) and periods in time (segments of the graph) the correct use of temporal prepositions appeared to form the gateway to conceptual knowledge. We only gained this insight during the third teaching experiment. Without continuous linguistic exploration of the domain we would not have become aware of this issue ourselves, nor would we have been able to raise the teacher's awareness. As a consequence, pupils would not have had the same access to conceptual knowledge related to line graphs.

Conducting linguistic explorations, however, will not be sufficient for realising language-oriented mathematics education. As described in the introductory chapter, previous research in the Netherlands has revealed that mathematics teachers tend to use language-avoiding strategies (Van den Boer, 2003). As a consequence mathematics classrooms have remained rather language-poor and multilingual pupils' language problems in mathematics classrooms have largely remained hidden. Exploratory research into language-oriented mathematics education (e.g., Van Eerde, Hajer, & Prenger, 2008) further showed the need for developing teacher strategies that can support pupils' development of subject-specific language needed for mathematical learning. We developed such strategies and the results have confirmed that the enactment of these strategies indeed led to whole-class scaffolding of subject-specific language. We recommend that enactment of these strategies will be explored in other mathematical domains (and subsequently in other areas of the curriculum) as well. In this way we hope that pupils can develop the domain-specific languages (pedagogical genres) with which they can contribute to mathematical classroom interaction, negotiate meanings, jointly explore mathematical subject matter and access domain-specific conceptual knowledge. Although the study was conducted at upper primary level, we argue that this way of linguistically supporting mathematical learning is also beneficial in lower primary and secondary education.

The realisation of language-oriented mathematics education will in our view only take place if attention is paid to the establishment of suitable social norms (Gravemeijer, 1995; Yackel & Cobb, 1996). Only when pupils know, for instance, that they can contribute verbally, can make mistakes, and take their time to find the right wordings, they will incrementally gain ground in language-oriented mathematics classrooms. To allow for the establishment of language-oriented RME classrooms the teacher's role of

"guider" of reinvention processes needs to be revisited. That is, to adequately and responsively support second language development we argue that a prominent and intervening teacher role is required. Thus, the teacher is to simultaneously impersonate the role of a guider of mathematical inventions, the "establisher" of the social norms required for an interactive and language-promoting classroom, as well as the "on-the-spot scaffolder of language" needed for mathematical learning. Although the RME-experienced teacher involved in our three teaching experiments in the early lessons indeed experienced a field of tension in integrating language and mathematics, she later on stated that the different teacher roles needed for this integration could well go together, provided that a trajectory of *practising scaffolding* and intensive professional development would take place. This brings us to the final recommendation concerning the realisation of language oriented (RME) mathematics education: to carefully attend to teachers' pre-service and in-service professional development. This seems to be especially required in the Dutch context in which in-service professional development receives little attention compared to other countries (Van den Heuvel-Panhuizen, 2012).

The issue of teachers' professional development entails further implications of a more general nature. In line with previous research in the area of content-based second language teaching, this study has shown that professional development is a crucial prerequisite if we are to really establish language-oriented content classrooms. After all, teachers cannot simply adopt a new way of teaching. A first issue to deal with concerns teachers' awareness: If they remain unaware of multilingual pupils' problems and the content literacy required for their disciplines (Love, 2009; Moschkovich, 2010), teachers cannot be expected to adaptively support language development. They may even remain resistant towards the idea of integrating content and language teaching (cf. Tan, 2011). The challenge is thus not only to foster awareness, but also teachers' beliefs concerning the necessity and possibility to scaffold multilingual pupils' language development. We note that this closely relates to having high expectations of multilingual pupils (Gibbons, 2009; Mariani, 1997).

To formulate recommendations for a professional development programme, we finally return to the key learning activities for teachers that Bakkenes, Vermunt, and Wubbels (2010) have observed to recur in the literature on teacher professional development. We now specify how these can be employed for realising language-oriented teaching (cf. Wayne, Suk Yoon, Zhu, Cronen, & Garet, 2008). Teachers can be stimulated to:

- experiment by (co-)developing HLTs in which content-specific and linguistic learning goals are specified, by enacting such language-oriented lessons themselves and by employing a repertoire of strategies for scaffolding language in doing so;

- interact with researchers, educators or colleagues about responsive enactment of language-supporting strategies and (how to diagnose) pupils' levels of language proficiency;
- read professional publications, for example on scaffolding language and content-based second language teaching, as well as on establishing social norms to create the conditions for this kind of teaching to happen;
- reflect on own practice by writing reflective reports (involving recurring foci of attention) and discuss these with colleagues or teacher educators; reflect by participating in a process of co-designing; reflect by viewing and discussing video recordings of own or others' lessons.

Although this way of promoting teachers' professional development is a time-consuming endeavour, we think that the pay-off will be worth the investment. In this thesis we have argued that language in mathematics education is not to be avoided, but something to put more central: More explicit attention to language in multilingual classrooms can promote mathematical learning. In this way "mathematics for all" (Freudenthal, 1991) can become reality in today's diverse classrooms.

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Summary

Summary

Against the background of increasing linguistic diversity in classrooms worldwide, we aimed to provide scientifically grounded insight into how language-oriented mathematics education can be designed, enacted and evaluated. We addressed the following main research question:

> *How can teachers in multilingual primary classrooms scaffold pupils' language required for mathematical learning?*

Chapter 1 presents the context for the study and describes its multidisciplinary nature (1.1). The variety of theoretical perspectives underlying this study is introduced. First, sociocultural theory is described (1.2) in terms of the core ideas relevant within this thesis, for example the joint construction of knowledge and the teacher's role of a more knowledgeable other. We point out the influence of sociocultural theory on education and on educational research, in particular on mathematics education reform movements and on the field of second language learning. Next, we introduce the key theoretical perspective of content-based second language teaching (1.3). We introduce existing models used in this field (e.g., the teaching and learning cycle) and describe international and national attempts to realise content-based second language teaching – in the latter case those focusing on mathematics education. The theory of realistic mathematics education (RME) is introduced as the domain-specific theory that informed the design of our lessons. In identifying the knowledge gap (1.4), Chapter 1 further introduces the central notion of scaffolding as a particular kind of responsive and temporary help, and relates this notion to pupils' (second) language development.

In a subsequent section (1.5) we provide information on the methodological approach taken in this study to find an answer to the main research question and on the teaching experiments conducted. As scaffolding of language in mathematics classrooms could not be studied in existing naturalistic settings, we needed a methodological approach in which such an innovative type of teaching and learning could be developed and studied. To this end, we conducted design research, which aims to yield innovative materials and to contribute to educational theory at the same time. Where in traditional research approaches theory is seen as standing apart from and above practice, design research regards theory as to emerge from practice and to feed back to guide it. In our design-based research project three teaching experiments were carried out in three classes of different suburban primary schools (age 10-12) with multilingual pupil populations. Chapter 1 introduces the mathematical domain central to the lessons (line graphs) and gives some background information on the nature of the language-oriented mathematics lessons in the Dutch context of RME.

We end Chapter 1 by clarifying the thesis' structure in relation to the main research question (1.6). To realise an innovative learning environment in which scaffolding of language for mathematical learning could take place, we needed a teacher who would be able to enact scaffolding. In the first two teaching experiments we therefore decided to enhance and investigate the participating teacher's learning process (Chapter 2), while simultaneously elaborating the idea of scaffolding language for mathematics education. We presumed that focusing on the teacher's learning could also contribute to our understanding of how to elaborate and enact scaffolding of language in our particular context. Having gained insights into how a teacher can learn to enact the scaffolding of language needed for mathematical learning, we address pupils' language learning processes in the third teaching experiment (Chapter 3). We also investigate the nature of this language itself and introduce the notion of pedagogical genre to refer to a genre that is deliberately designed for pedagogical purposes – in our case to support pupils' reasoning about line graphs. In the next two chapters (4 and 5) we centralise the support provided by the teacher, employing the concept of scaffolding. We first present a conceptualisation of whole-class scaffolding in response to the conceptual challenges we encountered when enacting scaffolding in whole-class settings (Chapter 4). Next, we address methodological challenges related to analysing whole-class scaffolding (Chapter 5).

We now summarise the research aim or question(s), the theoretical focus, the data used and the main findings of Chapters 2 to 5.

Chapter 2 addresses the question of how a teacher participating in dual design research learned to scaffold multilingual pupils' language development required for mathematical learning. Dual design research is a special case of design research that aims to promote and trace the development not only of the *pupils'* but also of the *teacher's* learning. This specific type of design research therefore well suited our purpose of studying and promoting the teacher's professional development with respect to scaffolding language. Besides, it well fitted with our research topic of scaffolding as scaffolding is a relational notion involving both *teacher* and *pupil* activity.

To meet the challenge of teaching in linguistically diverse mathematics classrooms, we introduced content-based language instruction as a fruitful approach. Following this approach, the development of pupils' (second) language ability can be integrated to teaching mathematics. Scaffolding language was described as a key strategy within content-based language instruction that promotes pupils' proficiency in the more academic genres (exemplified in target texts) necessary for participating in different areas of the curriculum (in our case mathematics). The teaching and learning cycle was presented as the design heuristic to be employed. This cycle consists of a series of four stages in which a particular

genre needed at school is introduced, modelled, jointly practised and eventually individually performed. Concerning teacher expertise development, we proposed to focus on awareness of multilingual issues (e.g., of pupils' difficulty with subject-specific language and the need to explicitly support language development) as a starting point for required expertise. To promote the teacher's awareness, the following key learning activities were derived from the literature: learning by experimenting, learning in interaction with others, using external sources and consciously reflecting on one's own teaching practices. We argued that dual design research is a suitable approach to capitalise on these learning activities as well as to fulfil our research purpose of gaining insight into how scaffolding can be performed and learned.

To answer the question central to Chapter 2, we addressed the following subquestions:

2.1 What can a teacher participating in dual design research learn in terms of scaffolding pupils' development of the language required for mathematical learning?

2.2 To what characteristics of dual design research can the participating teacher's learning process be attributed?

Instruments used to promote the teacher's learning included the hypothetical learning trajectory (HLT; used in the co-design process) and the reflection promoting video-stimulated recall interviews. Instruments to trace the teacher's learning were written interview schemes, used to determine her developing scaffolding expertise. Empirical data were collected from the first two teaching experiments, carried out in the last two grades of two suburban primary schools (age 10 to 12). These data included: audio and video recordings of all lessons, field notes, e-mail correspondence with the teacher, the teacher's reflective reports and pupils' pre- and posttest results as well as their written work. Furthermore, two preinterviews, two postinterviews and one post-postinterview with the teacher were audio-recorded, as were reflective conversations and stimulated recall interviews. All interviews were transcribed verbatim. These were used to analyse the teacher's self-reported and derived learning.

Analysis of the teacher's self-reported and derived learning pointed at the teacher's learning process in terms of changes in knowledge and beliefs, changes in practice and intentions for practice (research question 1). Concerning the category of knowledge and beliefs, for instance, the teacher became aware of the difficulty and necessity of adequately performing scaffolding strategies in multilingual classrooms and of multilingual pupils' hidden linguistic incompetence. She also increasingly acknowledged the need for multilingual pupils to participate actively in classroom discourse and produce subject-specific language. Her intentions became richer as well: At first her

intentions were only related to formulating more precisely, but from the second design cycle onwards the variety of reported intentions for practice increased. For example, she reported the intention to better integrate language in mathematics lessons.

To determine to which characteristics of dual design research the teacher's learning could be attributed (research question 2) we analysed all relevant written data, including reports of reflective discussions, transcripts of stimulated recall interviews and the teacher's reflective notes. This analysis showed that her learning process could be attributed to the characteristics of dual design research, for instance its cyclic and interventionist character, the continuous process of prediction and reflection that lies at its heart, and the process of co-designing complemented with the stimulated recall interviews. In particular the stimulated recall interviews were of crucial importance for raising the teacher's awareness. We concluded that dual design research seems a fruitful methodological approach to promote and investigate the teacher's learning processes, especially at the start of exploratory research.

Chapter 3 deals with two aspects of the main research question. First, it aims to specify the language required for mathematical learning (drawing on all three teaching experiments). Second, it aims to evaluate pupils' progress and development of the language required for reasoning about line graphs (drawing on data from the third teaching experiment). We drew on an approach called genre pedagogy to fulfil our first aim. The core idea of genre pedagogy is to focus explicitly on the ways language can be organised to achieve purposes in particular contexts. Such explicit attention to language is supposed to provide also second-language learning pupils with access to the official discourses of the classroom. Although the notion of genre is typically associated with particular literary forms of writing (e.g., a poem or a novel), in genre pedagogy the notion of genre is broadened to include forms of academic language with a specific purpose, organisation and specific language features. Six key genres are normally distinguished (recount, narrative, discussion, procedure, report and explanation) to describe the different types of language needed for participating throughout the curriculum, but also present in society. In Chapter 3, we introduce the notion of *pedagogical genre*. Such a pedagogical genre differs from genres as identified in genre pedagogy up to now in that it is deliberately designed as a learning goal. It is captured in terms of structure and linguistic features with examples as an instructional aid for teachers to focus their and pupils' attention on what matters most in talking or writing about a particular domain (in our case: line graphs).

Such deliberate moulding of a genre, we argue in Chapter 3, is a required step when we think through the consequences of the linguistic turn – the shift from a focus on

discipline-bound content to usage of language and its relation to human thinking – that has taken place in educational research. Instead of leaving the role of language implicit and epiphenomenal in educational design, we thus argue to position it right at the centre. Cutting across the different layers of theory that informed our study, the notion of pedagogical genre is argued to be potentially an ontological innovation in that it provided us with a new lens for making sense of what should be key in an instructional setting that attempts to deliberately incorporate the linguistic turn. Moreover, it helped us to scrutinise previously implicit aspects of design (cf. diSessa & Cobb, 2004).

The development of the pedagogical genre that we called *interpretative description of a line graph* is summarised. We describe how we formulated structure and linguistic features based on a literature study, an expert questioning round and empirical data. We further present the means that supported pupils' proficiency in the pedagogical genre: the teaching and learning cycle, the repertoire of scaffolding strategies and the use of the HLT to enhance both mathematical and language development.

In the empirical study presented in Chapter 3 we investigate pupils' language development. The following research questions served to evaluate whether pupils indeed developed proficiency in the pedagogical genre of *interpretative description of a line graph*:

3.1 To what extent did pupils make progress in deploying the pedagogical genre?

3.2 How can we characterise the development of pupils' genre proficiency?

To answer the first research question we drew on all pupils' independent writing in the targeted pedagogical genre in pre- and posttests, conducted before and after the third teaching experiment. We used two similar test items to investigate pupils' progress. In these test items pupils were asked to describe a line graph representing changes in a particular variable (e.g., uncle Kees's weight). Pupils' productive genre proficiency was analysed by two independent raters by means of an analytic model that was developed involving two scales; interrater reliabilities were high ($\kappa = .78$ and .79). In answer to the first research question, we concluded that pupils' genre proficiency increased to a large extent: The average score for pupils' writing in the pedagogical genre in the posttest was 2.89 points higher than their average score in the pretest, measured on a 10-point scale. This difference was statistically significant ($t = 8.37$; $df = 21$; $p < .001$), with an effect size of $d = 2.20$, which can be considered very large.

To answer the second research question, we conducted multiple case-study research including four bilingual pupils. We collected interview data from interviews lasting 10 to 15 minutes, held with these four pupils after each lesson. The interview scheme that we used included both general and lesson-specific questions. It further included guidelines

to steer researchers away from enactment of scaffolding strategies. To trace pupils' developing genre proficiency throughout the lesson series we analysed their spoken language produced during the interviews using an instrument informed by the HLTs formulated in designing the lessons. In answer to the second research question, we concluded that the four case-study pupils showed gradual development with some falling back over the course of the lessons. By and large their development was in line with what we had conjectured in the HLTs. For example, they all showed progress in the use of subject-specific language (e.g., rise, descend). Closer examination of individual learning processes revealed where the observed learning slightly diverged from the hypothesised learning. For none of the four case-study pupils providing graph descriptions in terms of reality (e.g., "slowly loses weight") *and* in terms of the course of the graph (e.g., descends gradually") had become a habit. Cases where hypothetical and observed learning differed indicate that even more time and attention should be directed towards supporting multilingual pupils' development of the required pedagogical genre. To us, this reinforces the need for a linguistic turn we propose for educational design.

Chapter 4 presents a conceptualisation of whole-class scaffolding. Referring to temporary and adaptive support, the concept of scaffolding has become widely used, also in whole-class settings. However, it has often been used in loose ways in terms of key characteristics of scaffolding that are not clearly distinguished. The term is even used for aspects of classroom organisation, artefacts and sequencing, which in our view is a form of overgeneralisation. Chapter 4 deals with these *conceptual challenges*. The aim of this chapter is to theoretically and empirically ground a conceptualisation of whole-class scaffolding that would stay as close as possible to the spirit of the origin of the scaffolding concept, but that would also leave room for features not salient in one-to-one interaction.

Drawing an analogy with Vygotsky's (1978) concept of ZPD (zone of proximal development), we first argued why the extension from one-to-one (teacher-pupil) to whole-class settings was justified. In line with the scaffolding literature, we subsequently distinguished three key characteristics of whole-class scaffolding: diagnosis, responsiveness and handover to independence. These were illustrated with examples from the third teaching experiment that focused on supporting pupils' proficiency in the pedagogical genre needed for reasoning about line graphs.

So far, scaffolding has mainly been conceptualised as happening in live dialogue only. However, our study pointed to the fact that parts of the scaffolding process can occur outside classroom interaction. Diagnoses can namely also be made outside lessons, for instance by analysing pupils' written work; responsiveness can also be realised in adapting instructional activities in between lessons; and handover to independence can

also be fostered in the design of lessons (in our case by employing the teaching and learning cycle). We therefore metaphorically distinguish between *online* and *offline* enactment of key characteristics of whole-class scaffolding; respectively *during* or *outside* whole-class interaction. Our empirical findings also point to more features of whole-class scaffolding that capture its nature. In addition to this *layered* nature (online vs. offline), whole-class scaffolding is often *distributed* over time. Finally, whole-class scaffolding is *cumulative*, with pupils' independence emerging as the cumulative effect of many diagnostic and responsive actions over time. We suggest these three features are at the core of whole-class scaffolding that is deliberately employed to foster long-term learning processes. Furthermore, we conjecture that the features of whole-class scaffolding that we identified may well hold for one-to-one scaffolding that goes beyond a brief interaction between a teacher and a pupil. As such our conceptualisation enriches the understanding of scaffolding more broadly.

Where in Chapter 4 we dealt with the conceptual challenges that arose when conducting research on whole-class scaffolding, in **Chapter 5** we centralise the *methodological challenges* of including pupils' leaning processes (handover) in the analysis of whole-class scaffolding as well as to analyse the key characteristics of diagnosis, responsiveness and handover also in relation to each other. We only wanted to assert whole-class scaffolding if a teacher diagnosed pupils' linguistic levels and responsively performed strategies, with indications of handover as a result. An implication of employing the conceptualisation of whole-class scaffolding as described in Chapter 4 was our wish to include the long-term nature of whole-class scaffolding in the analysis. As a consequence, we concluded that larger units of analysis than brief fragments of classroom interaction would be needed.

We investigated the teacher's use of a repertoire of seven strategies for scaffolding language (e.g., asking for more precise language; reformulating pupils' utterances) that had formed one of the yields of the first two teaching experiments. Our aim was to investigate whether the enactment of strategies intended to scaffold the development of subject-specific language in a multilingual upper primary mathematics classroom indeed led to whole-class scaffolding as identifiable by its key characteristics (diagnosis, responsiveness and handover to independence), taking into account the long-term nature of whole-class scaffolding. To fulfil this aim we addressed three research questions in response to the aforementioned methodological challenges.

5.1 To what extent did handover to independence take place?

5.2 What evidence of responsiveness can be identified in the teacher's enactment of strategies for promoting language development?

5.3 How are the performed strategies and characteristics (diagnosis, responsiveness and handover) of whole-class scaffolding related over time?

We used a selection of test items out of the pre- and a posttest to determine handover to independence (research question 1). These involved three linguistic key elements needed for reasoning about line graphs: a group of graph-related words (e.g., horizontal axis), the conceptually difficult key word 'gradually' and temporal prepositions (used to refer to moments or periods in time). Comparison of pupils' pre- and posttest scores on these three linguistic key elements all yielded statistically significant differences with large effect sizes, thus confirmed handover to independence.

To identify possible evidence of responsiveness (research question 2), we decided to frame the analysis of both pupils' language development and responsiveness of performed strategies within a larger time scale. After all, (second) language development is one of the topics of learning that take longer periods of time to pursue. Data included transcripts of all video and audio recordings of the third teaching experiment. Our hypothesis was that responsiveness over time should be visible in a shift from high-support strategies (in early lessons) to low-support strategies (in late lessons). High-support strategies involve a high level of teacher support and low-support strategies involve a low level of teacher support, thus posing bigger demands on pupils' independence. To examine such a shift a coding scheme with instructions was developed in several rounds and two independent raters coded a selection of early and late teacher utterances containing strategies for scaffolding language. A statistically significant shift from high-support to low-support teacher strategies revealed the teacher's responsiveness to pupils' linguistic levels over nine lessons.

A qualitative analysis, drawing on lesson and stimulated recall interview transcripts, showed interrelatedness of performed strategies and scaffolding characteristics (e.g., diagnosis) over time (research question 3). The results provided empirical evidence of the long-term realisation of whole-class scaffolding. In Chapter 1 we pointed to the need for investigations into teacher instruction that would successfully support specialised talk and writing in multilingual mathematics classrooms. Chapter 5 provides evidence for a teaching approach that, at least in the case central to this study, has proven to be successful in supporting multilingual pupils' development of specialised language for mathematical learning.

In sum

All in all, our study showed how teachers in multilingual primary classrooms can scaffold pupils' language required for mathematical learning. The participating teacher used instructional activities that we deliberately designed so as to scaffold pupils' descriptive

interpretations of line graphs. She constantly used a repertoire of strategies to support pupils' proficiency in the pedagogical genre of interpreting and describing line graphs. The empirical analyses indicate that the classroom interaction as shaped by the teacher could indeed be characterised as whole-class scaffolding: The teacher diagnosed and was responsive to pupils' written work and oral utterances, and she handed over to independence. Learning gains were statistically significant with large to very large effect sizes. Our study thus provides evidence of how language-oriented mathematics education can be designed, enacted and evaluated.

Samenvatting

Samenvatting

Dit proefschrift is gesitueerd tegen de achtergrond van de toenemende talige diversiteit in het onderwijs wereldwijd. Het onderzoeksdoel was om inzicht te verschaffen in hoe taalgericht reken-wiskundeonderwijs kan worden ontworpen, uitgevoerd en geëvalueerd. De hoofdvraag daarbij was:

> *Hoe kunnen leerkrachten in meertalige basisschoolklassen de talige ontwikkeling van leerlingen ondersteunen die nodig is voor het leren van rekenen-wiskunde?*

Hoofdstuk 1 schetst de context van het onderzoek en beschrijft de theoretische perspectieven die eraan ten grondslag liggen. Eerst beschrijven we de kernideeën uit sociaal-culturele theorieën die relevant zijn binnen dit onderzoek (1.2), bijvoorbeeld het idee van gezamenlijke kennisconstructie en het idee van de docent als *more knowledgeable other* (meer wetende ander). We beschrijven vervolgens de invloed van sociaal-culturele theorieën op onderwijs en onderwijsonderzoek, in het bijzonder de invloed op innovaties in het reken-wiskundeonderwijs en op opvattingen over het leren van een tweede taal. Gerelateerd aan tweedetaalverwerving staat daarna de benadering van *content-based language instruction* (op inhoud gebaseerd taalonderwijs) centraal (1.3). We introduceren bestaande modellen waarmee *content-based language instruction* wordt vormgegeven, bijvoorbeeld de onderwijs-leercyclus, en we schetsen eerdere initiatieven om *content-based language instruction* te realiseren (met name voor rekenen-wiskunde). De theorie van realistisch reken-wiskundeonderwijs is de domein-specifieke instructietheorie die medebepalend was voor het ontwerp van de lessen binnen dit onderzoek. In hoofdstuk 1 introduceren we ook het centrale begrip *scaffolding* (1.4), dat refereert aan een specifiek soort tijdelijke, responsieve hulp, en dat binnen dit onderzoek betrekking heeft op het ondersteunen van (tweede)taalverwerving in de reken-wiskundeles.

In paragraaf 1.5 gaan we in op de methodologische aanpak waarmee we antwoord op de hoofdvraag hebben proberen te vinden, en beschrijven we de belangrijkste elementen van de uitgevoerde onderwijsexperimenten. Omdat we *scaffolding* van taal niet in bestaande reken-wiskundeklassen konden bestuderen en wilden weten hoe die te realiseren, hadden we een methodologische aanpak nodig waarmee we een dergelijke innovatieve leeromgeving konden ontwikkelen én bestuderen. Daarom hebben we ontwikkelingsonderzoek uitgevoerd, waarbij zowel innovatieve materialen als onderwijstheorie worden ontwikkeld. Ons ontwikkelingsonderzoeksproject behelste drie onderwijsexperimenten, die op drie verschillende multiculturele basisscholen (leeftijd: 10–12) zijn uitgevoerd. Hoofdstuk 1 introduceert het reken-wiskundige domein dat centraal staat in de lessen (lijngrafieken) en geeft achtergrondinformatie over de taalgerichte rekenlessen in de Nederlandse context van realistisch reken-wiskundeonderwijs.

Aan het einde van hoofdstuk 1 geven we de structuur van dit proefschrift weer in relatie tot de hoofdvraag (1.6). Om een innovatieve leeromgeving te creëren waarin *scaffolding* van taal voor het leren van rekenen-wiskunde plaats kon vinden, hadden we een docent nodig die al de nodige ervaring had met interactief reken-wiskundeonderwijs, en in staat zou zijn om zulke talige ondersteuning te bieden. In de eerste twee experimenten besloten we om die reden om het leerproces van de betrokken docent bewust te bevorderen en te bestuderen (hoofdstuk 2), terwijl we tegelijkertijd het idee van *scaffolding* van taal voor reken-wiskundeonderwijs verder wilden uitwerken. Daarbij veronderstelden we dat de focus op het leerproces van de betrokken docent ook inzicht kon geven in hoe het idee van *scaffolding* van taal kon worden uitgewerkt en hoe het in de praktijk kon zou kunnen worden gebracht in onze specifieke context. Na hierin inzicht te hebben verkregen, verlegden we de focus en stelden we de taalontwikkeling van de leerlingen centraal (hoofdstuk 3). Dit betekende dat we ook de aard van de te ontwikkelen taal moesten onderzoeken en het resultaat daarvan was de introductie van de notie *pedagogical genre* (didactisch genre). Hiermee refereren we aan een tekstgenre dat bewust is ontworpen voor didactische doeleinden - in ons geval om over lijngrafieken te leren redeneren. In de volgende twee hoofdstukken (hoofdstuk 4 en 5) richten we de aandacht op de talige hulp die de docent biedt, waarbij we het begrip *scaffolding* gebruiken. Eerst stellen we een conceptualisatie van *whole-class scaffolding* (talige ondersteuning in klassikale situaties) voor als antwoord op de conceptuele uitdagingen die op ons pad kwamen toen we *whole-class scaffolding* wilden realiseren (hoofdstuk 4). Vervolgens kaarten we de methodologische uitdagingen aan die zijn gerelateerd aan het analyseren van *whole-class scaffolding* (hoofstuk 5).

We vatten hieronder het onderzoeksdoel, de onderzoeksvragen, de theoretische oriëntaties, de geanalyseerde data en de belangrijkste bevindingen van de hoofdstukken 2 tot en met 5 samen.

In **hoofdstuk 2** is de centrale vraag hoe een docent die deelnam aan *dual design research* (duaal ontwikkelingsonderzoek) heeft geleerd om *scaffolding* van taal binnen de rekenles te realiseren. *Dual design research* is een speciaal type ontwikkelingsonderzoek waarbij ernaar wordt gestreefd om niet alleen het leerproces van de leerlingen, maar ook dat van de docent te bevorderen en te onderzoeken. Deze vorm van ontwikkelingsonderzoek sloot goed aan bij het onderzoeksdoel om *scaffolding* van taal door de docent te bevorderen en te onderzoeken. Niet alleen omdat *scaffolding* in eerste instantie door de docent moet worden gerealiseerd, maar ook omdat *scaffolding* een relationeel begrip is: het behelst docentactiviteit in relatie tot leerlingactiviteit.

Content-based language instruction vormde het theoretisch raamwerk. Bij deze benadering wordt (tweede)taalonderwijs geïntegreerd in het onderwijzen van een bepaald vak (in dit onderzoek: rekenen-wiskunde). *Scaffolding* van taal is een kernstrategie binnen deze benadering van *content-based language instruction*, omdat deze strategie leerlingen helpt zich de meer "academische" of schoolse tekstgenres die nodig zijn binnen de verschillende schoolvakken eigen te maken. In ons geval betrof het genre de taal die nodig is om over lijngrafieken te redeneren. De zogeheten onderwijs-leercyclus is de gebruikte ontwerpheuristiek om ontwikkeling van dit genre te bevorderen. Deze cyclus bestaat uit vier fasen, waarin een tekstgenre achtereenvolgens wordt geïntroduceerd, gemodelleerd, gezamenlijk beoefend en uiteindelijk individueel geproduceerd. Voor het professionaliseren van de betrokken docent besloten we op basis van de literatuur om ons in eerste instantie te richten op haar bewustwording van problemen die specifiek samenhangen met de meertalige achtergrond van leerlingen (bijvoorbeeld het feit dat tweetalige leerlingen niet de benodigde vaktaal verwerven alleen door het deelnemen aan klasseninteractie). Voor het bevorderen van zulk bewustzijn van docenten, worden de volgende leeractiviteiten aangedragen in de literatuur over professionalisering van docenten: leren door te experimenteren, leren in interactie met anderen, externe bronnen gebruiken, en bewust reflecteren op het eigen handelen in de klas. *Dual design research* leek een kansrijke aanpak om deze vier leeractiviteiten centraal te stellen en tegelijkertijd inzicht te verwerven in hoe *scaffolding* van taal kon worden gerealiseerd en geleerd.

Om de onderzoeksvraag van hoofdstuk 2 te kunnen beantwoorden, hebben we de volgende deelvragen centraal gesteld:

> *2.1 Wat kan een docent die deelneemt aan* dual design research *leren over* scaffolding *van de taal die de leerlingen nodig hebben om rekenen-wiskunde te leren?*
>
> *2.2 Aan welke kenmerken van* dual design research *kan het leerproces van de betrokken docent worden toegeschreven?*

We hebben twee typen onderzoeksinstrumenten gebruikt. Ten eerste betroffen dat onderzoeksinstrumenten om het leerproces van de docent te *bevorderen*, zoals het hypothetisch leertraject (ingezet bij het gezamenlijk ontwerpen van lessen) en reflectiebevorderende *video-stimulated recall interviews.* Ten tweede hebben we voor het *volgen* van het leerproces van de docent interviewschema's gebruikt waarmee we haar expertiseontwikkeling op het gebied van *scaffolding* van taal in kaart konden brengen. We hebben data gebruikt uit de eerste twee onderwijsexperimenten, die we uitgevoerd hebben op twee multiculturele basisscholen bij leerlingen van 10 tot 12 jaar. Deze data

betroffen: audio- en video-opnames van alle lessen, veldnotities, emailcorrespondentie met de docent, de reflectieverslagen door de docent, de voor- en natoetsresultaten van de leerlingen, en het schriftelijk werk van de leerlingen. Daarnaast hebben we opnames gemaakt van twee pre-interviews, twee post-interviews en één post-post-interview met de docent, evenals van reflectieve nabesprekingen van lessen en *video-stimulated recall interviews*. Alle interviews zijn letterlijk getranscribeerd. De transcripties zijn gebruikt om het zelf-gerapporteerde en het afgeleide leren – het leren dat uit de interviews kon worden afgeleid – van de docent te analyseren.

Analyse van het zelf-gerapporteerde en het afgeleide leren van de docent wees uit dat haar leerproces zich op de volgende manieren manifesteerde: veranderingen in kennis en opvattingen, veranderingen in haar lespraktijk en intenties voor haar lespraktijk (deelvraag 1). Veranderde kennis en opvattingen bleken onder meer uit haar toegenomen bewustzijn aangaande de moeilijkheid en de noodzaak om in meertalige klassen *scaffolding*-strategieën te bieden. Ze benadrukte ook in toenemende mate hoe belangrijk het voor de tweedetaalontwikkeling van meertalige leerlingen is om actief deel te nemen aan klasseninteractie en daarbij zelf vaktaal te gebruiken. Haar intenties werden ook rijker: in het begin hadden deze vooral betrekking op preciezer formuleren, maar vanaf het tweede onderwijsexperiment sprak de docent een grotere variëteit aan intenties uit. Ze stelde bijvoorbeeld voor om taal beter in haar rekenlessen te integreren.

Om vast te stellen aan welke karakteristieken van *dual design research* het leerproces van de docent kon worden toegeschreven (deelvraag 2) hebben we alle relevante schriftelijke data geanalyseerd: verslagen van reflectieve nabesprekingen van lessen, transcripten van *video-stimulated recall interviews* en reflectieverslagen door de docent. Deze analyse wees uit dat het leerproces van de docent kon worden toegeschreven aan de kenmerken van *dual design research*, bijvoorbeeld aan het cyclische en interventionistische karakter, aan het proces van voorspellen en reflecteren, en aan het gezamenlijk ontwerpen van lessen in combinatie met de *video-stimulated recall interviews*. In het bijzonder de *video-stimulated recall interviews* waren van cruciaal belang om het bewustzijn van de docent te bevorderen. De conclusie van hoofdstuk 2 was dat *dual design research* een vruchtbare methodologische aanpak is om het leerproces van een docent te bevorderen en te volgen, vooral aan het begin van innovatief onderzoek.

Hoofdstuk 3 gaat in op twee aspecten van de hoofdvraag binnen dit onderzoek. Het eerste doel is om de taal die nodig is voor het leren van wiskunde (gebaseerd op data uit alle drie onderwijsexperimenten) te specificeren. Het tweede doel is om te evalueren of leerlingen de taal die nodig is om te kunnen redeneren over lijngrafieken inderdaad ontwikkelden (op basis van data uit het derde onderwijsexperiment). Om ons eerste doel

te bereiken, hebben we gebruikgemaakt van een benadering die bekend staat als genredidactiek. De kern van genredidactiek is dat er expliciet gefocust wordt op hoe taal kan worden gebruikte om in een specifieke context doelen te bereiken. Er wordt verondersteld dat zulke expliciete aandacht voor taal ook meertalige leerlingen toegang geeft tot de officiële schoolse taal. Hoewel het idee van genre normaal gesproken wordt geassocieerd met specifieke literaire teksttypen (bijvoorbeeld een gedicht of een roman), wordt in genredidactiek het idee van genre breder gezien; het omvat daarbij ook schoolse teksttypen met een specifiek doel en bepaalde structuur- en talige structuurkenmerken, die op bepaalde manieren kunnen worden ingezet. Over het algemeen worden er zes kerngenres onderscheiden (verhaal, betoog, procedure, rapportage, verslag, uitleg) die nodig zijn voor participatie in het hele schoolse curriculum, maar deze genres komen ook in de maatschappij voor. In hoofdstuk 3 introduceren we het idee van *pedagogical genre* (didactisch genre). Een dergelijk *pedagogical genre* verschilt van de genres zoals die tot nu toe in genredidactiek zijn geïdentificeerd doordat het bewust is ontworpen als leerdoel in de vorm van structuur- en talige kenmerken met bijbehorende voorbeelden. Deze kenmerken en voorbeelden dienen als didactisch hulpmiddel voor docenten: hun aandacht en die van de leerlingen wordt gericht op wat het belangrijkste is bij het praten of schrijven over een specifiek domein (in ons geval: lijngrafieken).

Dit doelbewust ontwerpen van een genre, zoals we beargumenteren in hoofdstuk 3, is een noodzakelijke stap als we de consequenties aanvaarden van de talige wending die heeft plaatsgevonden in onderwijstheorie. Met deze wending bedoelen we de verschuiving van aandacht voor vakgerelateerde inhoud naar het gebruik van taal binnen de vakken, en naar hoe dit zich verhoudt tot het menselijk denken. In plaats van dat we de rol van taal in onderwijsontwerp impliciet en perifeer laten, stellen we taal juist centraal in het ontwerpproces. We betogen dat het idee van *pedagogical genre* in potentie een ontologische vernieuwing is, omdat het zich bevindt op het snijvlak van de verschillende lagen theorie die aan de basis van ons onderzoek liggen, en omdat het ons een nieuw perspectief biedt om te begrijpen wat belangrijk is in een onderwijssetting waarbinnen ernaar wordt gestreefd om de talige wending bewust vorm te geven. Bovendien helpt de notie van *pedagogical genre* ons om voorheen impliciete ontwerpaspecten nauwkeurig te onderzoeken.

We beschrijven de ontwikkeling van het *pedagogical genre* dat we *interpretatieve beschrijving van een lijngrafiek* hebben genoemd. Daarbij beschrijven we hoe we de geformuleerde structuur- en talige kenmerken baseerden op een literatuurstudie, een expertondervraging en empirische data. Verder laten we de middelen zien waarmee de vaardigheid van leerlingen in het *pedagogical genre* werd ondersteund: de onderwijs-

leercyclus, het repertoire van *scaffolding*-strategieën, en het gebruik van het HLT om zowel wiskundige als talige ontwikkeling te bevorderen.

In het empirisch gerichte hoofdstuk 3 onderzoeken we de taalontwikkeling van leerlingen. Met de volgende deelvragen wilden we evalueren of leerlingen inderdaad bekwamer werden in het beoogde pedagogical genre (interpretatieve beschrijving van een lijngrafiek):

3.1 In hoeverre nam de vaardigheid van leerlingen in het pedagogical genre toe?

3.2 Hoe kunnen we de ontwikkeling van deze genrevaardigheid karakteriseren?

Om de eerste onderzoeksvraag te beantwoorden, gebruikten we toetsitems uit de voor- en natoets van het derde onderwijsexperiment, waarin leerlingen zelfstandig in het beoogde *pedagogical genre* moesten schrijven (een interpretatieve beschrijving van een lijngrafiek moesten maken). Om de vooruitgang van de leerlingen vast te stellen, vergeleken we de resultaten op twee vergelijkbare toetsitems van beide toetsen. Om de productieve genrevaardigheid van leerlingen op deze items te analyseren, werden de leerlingteksten door twee onafhankelijke beoordelaars gescoord met behulp van een ontwikkeld scoremodel dat gebruikmaakte van zowel een ordinale als een rationale schaal; de betrouwbaarheid tussen de beoordelaars was hoog (κ = .78 en .79). In antwoord op de eerste onderzoeksvraag concludeerden we dat de genrevaardigheid van de leerlingen in grote mate toenam: de gemiddelde score gemeten op een tienpuntsschaal was in de natoets 2.89 punten hoger dan hun gemiddelde score in de voortoets. Dit verschil was statistisch significant (t = 8.37; df = 21; $p < .001$), met een effectgrootte van d = 2.20; dit getal duidt op een zeer groot effect.

Om de tweede onderzoeksvraag te beantwoorden, hebben we een meervoudige *case study* uitgevoerd met vier tweetalige leerlingen. We verzamelden gegevens van korte interviews met deze vier leerlingen (tien tot vijftien minuten per interview), die we hielden na afloop van iedere les. Het interviewschema dat we gebruikten, bevatte zowel algemene als lesspecifieke vragen. Verder bevatte het richtlijnen om ervoor te zorgen dat de onderzoekers zelf geen *scaffolding*-strategieën zouden bieden. Om de ontwikkeling van de genrevaardigheid van leerlingen tijdens de lessenserie te volgen, analyseerden we de gesproken taal die de leerlingen tijdens de interviews gebruikten met een analyse-instrument dat gebaseerd was op de HLT's die waren opgesteld bij het ontwerpen van de lessen. In antwoord op de tweede onderzoeksvraag concludeerden we dat er bij de vier *case study*-leerlingen in de loop van de lessenserie een geleidelijke ontwikkeling te zien was met nu en dan een terugval. In grote lijnen beantwoordde deze ontwikkeling aan onze vermoedens die we in de HLT's hadden geformuleerd. Alle leerlingen toonden

bijvoorbeeld vooruitgang op het punt van vaktaal (bijvoorbeeld het gebruik van de woorden "stijgen", "dalen"). Nader onderzoek van individuele leerprocessen liet zien waar het waargenomen leren licht afweek van het hypothetische leren. De vier *case study*-leerlingen hadden geen van allen de gewoonte ontwikkeld om in beschrijvingen van de grafiek zowel de werkelijkheid, met gebruik van schooltaal, te beschrijven (bijvoorbeeld "wordt langzaam lichter") als een beschrijving van het verloop van de grafiek te geven met gebruik van vaktaal (bijvoorbeeld "daalt geleidelijk"). Gevallen waar er een verschil was tussen het waargenomen en het voorspelde leerproces geven aan dat er nog meer tijd en aandacht geschonken moet worden aan het bevorderen van de genrevaardigheid van de leerlingen. Voor ons bevestigt dit het idee dat de talige wending die in onderwijstheorie heeft plaatsgevonden, ook gerealiseerd moet worden in onderwijsontwerp.

Hoofdstuk 4 beschrijft een conceptualisatie van *whole-class scaffolding* (talige ondersteuning die in klassikale discussie door de docent wordt geboden). Het begrip *scaffolding* is wijdverspreid en verwijst naar een specifiek soort tijdelijke en adaptieve hulp. Tegenwoordig wordt het ook gebruikt voor hulp die in klassikaal verband wordt geboden. Het begrip *scaffolding* wordt echter vaak te snel gebruikt voor typen hulp die niet duidelijk eigenschappen van *scaffolding* in zich dragen. Het begrip wordt zelfs gebruikt voor aspecten van klassenmanagement en voor bepaalde didactische tools, waarmee naar ons idee een vorm van overgeneralisatie plaatsvindt. Hoofdstuk 4 gaat in op deze conceptuele uitdagingen. Het doel van dit hoofdstuk is om een theoretisch en empirisch gegronde conceptualisatie van *whole-class scaffolding* te presenteren, die zo dicht mogelijk bij de oorsprong van het begrip *scaffolding* blijft, maar wel ruimte laat voor kenmerken die niet in het oog springen bij een-op-een interactie.

In analogie met Vygotsky's (1978) *zone of proximal development* (ZPD, zone van naaste ontwikkeling), hebben we eerst onderbouwd waarom de uitbreiding van *scaffolding* in een-op-eensituaties naar een klassikaal kader gerechtvaardigd was. In navolging van de literatuur over *scaffolding*, onderscheidden we vervolgens drie karakteristieken van *whole-class scaffolding*: diagnose, responsiviteit en overdracht naar zelfstandigheid. Deze werden geïllustreerd met voorbeelden uit het derde onderwijsexperiment dat zich richtte op het ondersteunen van de vaardigheid van leerlingen in het pedagogical genre dat nodig was om over lijngrafieken te redeneren.

Tot op heden is *scaffolding* voornamelijk geconceptualiseerd in de context van live dialoog. In ons onderzoek kwam echter naar voren dat delen van het *scaffolding*-proces zich buiten de klassikale interactie kunnen afspelen. Diagnoses kunnen namelijk ook buiten lessen worden gesteld, bijvoorbeeld bij het analyseren van het geschreven werk

van leerlingen; responsiviteit kan ook vormgegeven worden in het aanpassen van onderwijsactiviteiten tussen lessen in; en overdracht naar zelfstandigheid kan ook bevorderd worden in de lesontwerpen zelf (in ons geval door gebruik te maken van de onderwijs-leercyclus). We onderscheiden daarom metaforisch gesproken *online* en *offline* uitvoering van karakteristieken van *whole-class scaffolding*; respectievelijk *tijdens* of *buiten* klassikale interactie. Onze empirische resultaten laten bovendien zien dat er meer kenmerken van *whole-class scaffolding* zijn. Naast het *gelaagde* karakter (*online* vs. *offline*), is *whole-class scaffolding* vaak ook over de tijd *verspreid*. Tot slot is *whole-class scaffolding* ook *cumulatief*, waarbij de zelfstandigheid van leerlingen ontstaat als het cumulatieve effect van vele diagnostische en responsieve handelingen in de loop der tijd. Wij veronderstellen dat deze drie kenmerken aan de basis liggen van *whole-class scaffolding* dat doelbewust wordt ingezet om lange-termijnleereffecten te bereiken. Verder vermoeden wij dat de kenmerken van *whole-class scaffolding* die wij hebben geïdentificeerd, wellicht ook een rol spelen bij een-op-een *scaffolding* als die verder gaat dan een korte interactie tussen leraar en leerling. Als zodanig verrijkt onze conceptualisering het begrip van *scaffolding* in ruimere zin.

Waar in hoofdstuk 4 de conceptuele uitdagingen van onderzoek naar *whole-class scaffolding* centraal stonden, staan in **hoofdstuk 5** de volgende methodologische uitdagingen centraal: de overdracht naar zelfstandigheid deel uit te laten maken van de analyse van *whole-class scaffolding*, responsiviteit te identificeren, en diagnose, responsiviteit en overdracht naar zelfstandigheid in relatie tot elkaar te analyseren. We wilden namelijk alleen maar van *whole-class scaffolding* spreken wanneer de docent het talige niveau van de leerlingen diagnosticeerde, strategieën responsief bood, en als er indicaties waren dat overdracht naar zelfstandigheid had plaatsgevonden. Een implicatie van het uitgaan van de conceptualisatie zoals beschreven in hoofdstuk 2 was dat we het langetermijnkarakter van *whole-class scaffolding* deel van de analyse wilden laten zijn. Daarom besloten we dat de eenheid van analyse meer zou moeten omvatten dan korte fragmenten van klasseninteractie.

We hebben onderzocht hoe de docent gebruikmaakte van een repertoire van *scaffolding*-strategieën dat de eerste twee onderwijsexperimenten hadden opgeleverd (bijvoorbeeld vragen om preciezere formulering; herformuleren van leerlinguitingen). Het doel was om te onderzoeken of het bieden van deze *scaffolding*-strategieën, die bedoeld waren om de ontwikkeling van vaktaal in een meertalige basisschoolklas te bevorderen, ook echt leidde tot *whole-class scaffolding* zoals we het geconceptualiseerd hadden (namelijk als de manifestatie van diagnose, responsiviteit en overdracht naar zelfstandigheid). Hierbij wilden we ook het langetermijnkarakter van *whole-class scaffolding* in acht nemen. Om dit onderzoeksdoel te realiseren, hebben we de volgende deelvragen geformuleerd:

5.1 In hoeverre vond er overdracht naar zelfstandigheid plaats?

5.2 Welk bewijs van responsiviteit kan worden geïdentificeerd in het bieden van taalondersteunende strategieën door de docent?

5.3 Hoe zijn de geboden strategieën en de karakteristieken van whole-class scaffolding *(diagnose, responsiviteit en overdracht naar zelfstandigheid) gerelateerd door de tijd heen?*

We hebben een selectie van de toetsitems uit de voor- en natoets gebruikt om overdracht naar zelfstandigheid vast te stellen (deelvraag 1). Deze items betroffen drie linguïstische kernelementen die nodig waren om over lijngrafieken te redeneren: een groep aan lijngrafieken gerelateerde woorden (bijvoorbeeld horizontale as), een conceptueel lastig kernbegrip, namelijk "geleidelijk", en tijdsaanduidende voorzetsels en bijwoorden (die gebruikt werden om naar momenten of periodes in de tijd te verwijzen, bijvoorbeeld "van...tot"). De vergelijking van voor- en natoetsresultaten liet voor deze drie linguïstische kernelementen statistisch significante verschillen zien met een forse effectgrootte. Dit bevestigde dat er overdracht naar talige zelfstandigheid had plaatsgevonden.

Om na te gaan of er sprake was van responsiviteit (deelvraag 2), besloten we om de taalontwikkeling van de leerlingen en de responsiviteit van de geboden strategieën over een langere tijdsperiode (negen lessen) te analyseren. Tweedetaalontwikkeling is immers iets wat bij uitstek tijd vraagt. De data bestonden uit transcripten van alle video- en audio-opnames van het derde onderwijsexperiment. Onze hypothese was dat langetermijnresponsiviteit zichtbaar zou zijn in een verschuiving van veel ondersteuning biedende strategieën (in vroege lessen) naar weinig ondersteuning biedende strategieën (in late lessen). Weinig ondersteuning biedende strategieën stellen namelijk hogere talige eisen aan de leerlingen – iets wat in late lessen beter mogelijk zou moeten zijn. Om te analyseren of zo'n verschuiving daadwerkelijk had plaatsgevonden, ontwikkelden we in meerdere rondes een codeerschema met bijbehorende codeerinstructies, waarna twee onafhankelijke beoordelaars een selectie codeerden van vroege en late docentuitingen waarin zij een taalondersteunende strategie bood. Een statistische significante verschuiving van veel ondersteuning biedende strategieën naar weinig ondersteuning biedende strategieën duidde erop dat de docent de leerlingen op een responsieve manier talige ondersteuning had geboden.

Een kwalitatieve analyse, waarbij we gebruikmaakten van transcripten van lessen en *video-stimulated recall interviews*, liet zien hoe de geboden strategieën en de karakteristieken van *whole-class scaffolding* (bijvoorbeeld diagnose) met elkaar verbonden waren door de tijd heen (deelvraag 3). De resultaten van de in hoofdstuk 5 gepresenteerde studie vormden

empirisch bewijs voor het realiseren van *whole-class scaffolding* over een langere periode van tijd. In hoofdstuk 1 wezen we op de noodzaak van onderzoek naar docentinstructie die vakgebonden vormen van spreken en schrijven in meertalige klassen goed kan ondersteunen. Hoofdstuk 5 laat zo'n vorm van docentinstructie zien, die in ieder geval in dit onderzoek naar talige ondersteuning in meertalige rekenklassen succesvol bleek te zijn.

Tot slot

Dit promotieonderzoek heeft laten zien hoe docenten in meertalige klassen door *scaffolding* van taal ondersteuning kunnen bieden bij het verwerven van de voor rekenen-wiskunde benodigde taal. De deelnemende docent voerde lesactiviteiten uit die wij specifiek hadden ontworpen om leerlingen te ondersteunen bij het beschrijven en interpreteren van lijngrafieken. Ze maakte veelvuldig gebruik van het geboden repertoire van *scaffolding*-strategieën waarmee ze de taalontwikkeling van de leerlingen in het beoogde *pedagogical genre* (didactische genre) bevorderde. De empirische analyses laten zien dat de klasseninteractie zoals (mede)vormgegeven door de docent inderdaad gekarakteriseerd kan worden als *whole-class scaffolding*: de docent stelde diagnoses over de taalvaardigheid van de leerlingen, ze reageerde responsief op hun mondelinge en schriftelijke taaluitingen, en ze zorgde voor overdracht naar talige zelfstandigheid. De leerwinst was statistisch significant met forse effectgroottes. Dit onderzoek levert dus aanwijzingen voor hoe taalgericht reken-wiskundeonderwijs kan worden ontworpen, uitgevoerd en geëvalueerd.

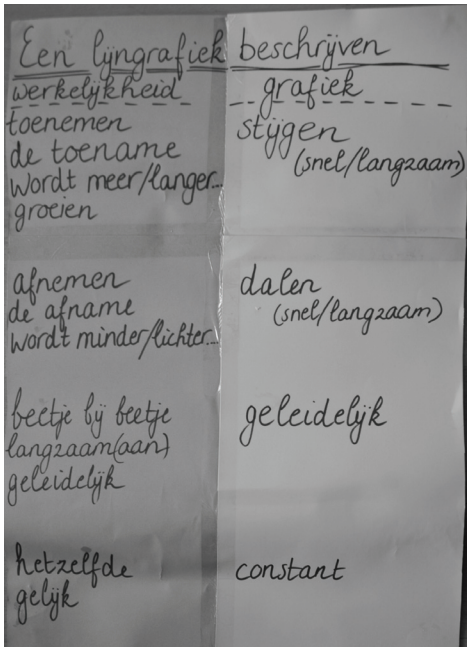
Appendices

Appendix A. Lesson descriptions and exemplary materials

These descriptions have been formulated in retrospect for the reader, to give a sense of what the lessons looked like. They were not part of the HLTs or the teacher guide.

Lesson 1

At the start of the first lesson, pupils get to know the teacher (who is not the regular class teacher). The nature of the language-oriented mathematics lessons is discussed: Introduction of the word list (Figure 1) on which general academic and subject-specific words will be written throughout the lessons. Introduction of the social norms that are needed to allow for a classroom climate in which language-oriented mathematics teaching can take place. These norms include, for example: we listen to each other and we want to understand each other. Instructional activity about Koen's growth which follows a discussion on a given data set (Figure 2). Pupils are asked: "Can you make up an image that better follows Koen's growth?" In response to this question pupils make their own representations in small groups. Subsequently, each small group chooses one representation that is considered "the best". This representation is put on a large poster. Introduction of words such as: *length*, *measurement data*, *table* and *growth*.



Describing a line graph	
reality	graph
increase	rise (slow/fast)
the increase becomes more/ taller	
grow	
decrease the decrease becomes less/ lighter	descend (slow/fast)
little by little slow(ly) gradually	gradually
the same equal	constant

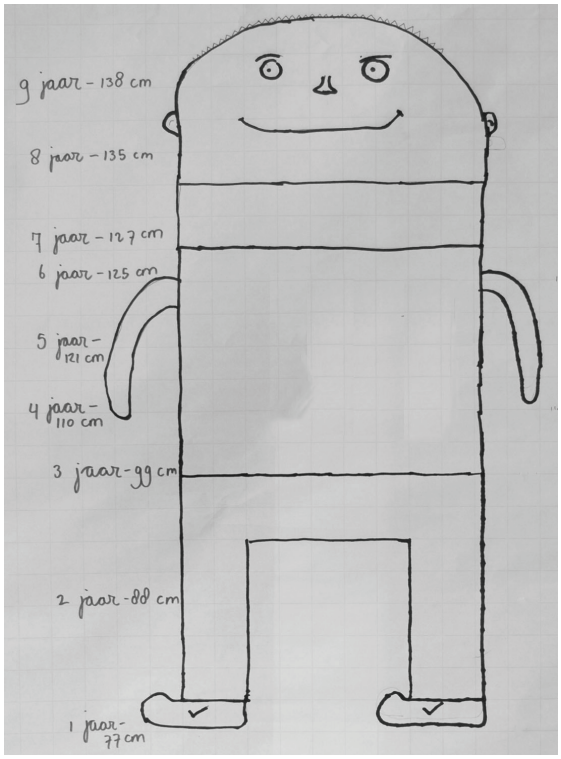
Figure 1 Word list at the end of the third teaching experiment

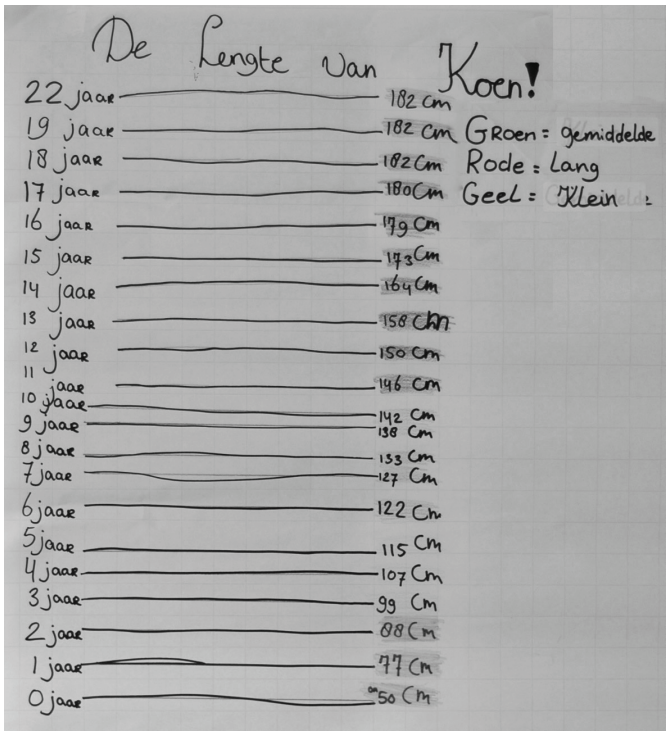
22 years	182 cm
18 years	182 cm
16 years	179 cm
9 years	138 cm
7 years	127 cm
2 years	88 cm
1 year	77 cm

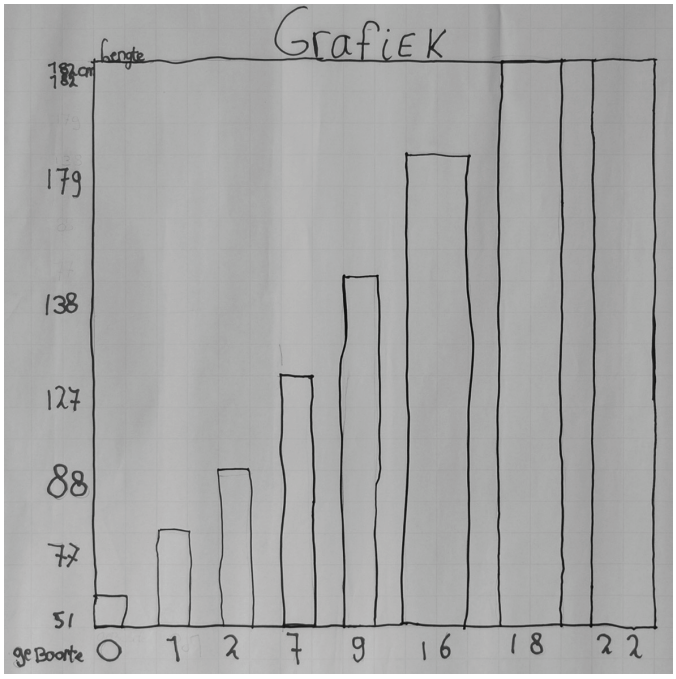
Figure 2 Data set of Koen's growth over the years

Lesson 2

Pupils prepare poster presentations in the same small groups as in the previous lesson. Each group gives a brief poster presentation in which they tell about the representation they came up with (Figure 3). The presentations are each followed by a whole-class discussion, guided by the teacher. The line graph comes to the fore as the most suitable representation for the given data. In comparing the different representations several subject-specific words are introduced: *line graph*, *bar graph*, *bias*, *course* (*of the graph*), *horizontal axis*, *vertical axis*.




De Lengte van Koen!
22 jaar 182 cm
19 jaar 182 cm
18 jaar 182 cm
17 jaar 180 cm
16 jaar 179 cm
15 jaar 173 cm
14 jaar 164 cm
13 jaar 158 cm
12 jaar 150 cm
11 jaar 146 cm
10 jaar 142 cm
9 jaar 138 cm
8 jaar 133 cm
7 jaar 127 cm
6 jaar 122 cm
5 jaar 115 cm
4 jaar 107 cm
3 jaar 99 cm
2 jaar 88 cm
1 jaar 77 cm
0 jaar 50 cm
Groen = gemiddelde
Rode = Lang
Geel = Klein


Grafiek
lengte
182 cm
182
179
138
127
88
77
51
geboorte
0
1
2
7
9
16
18
22

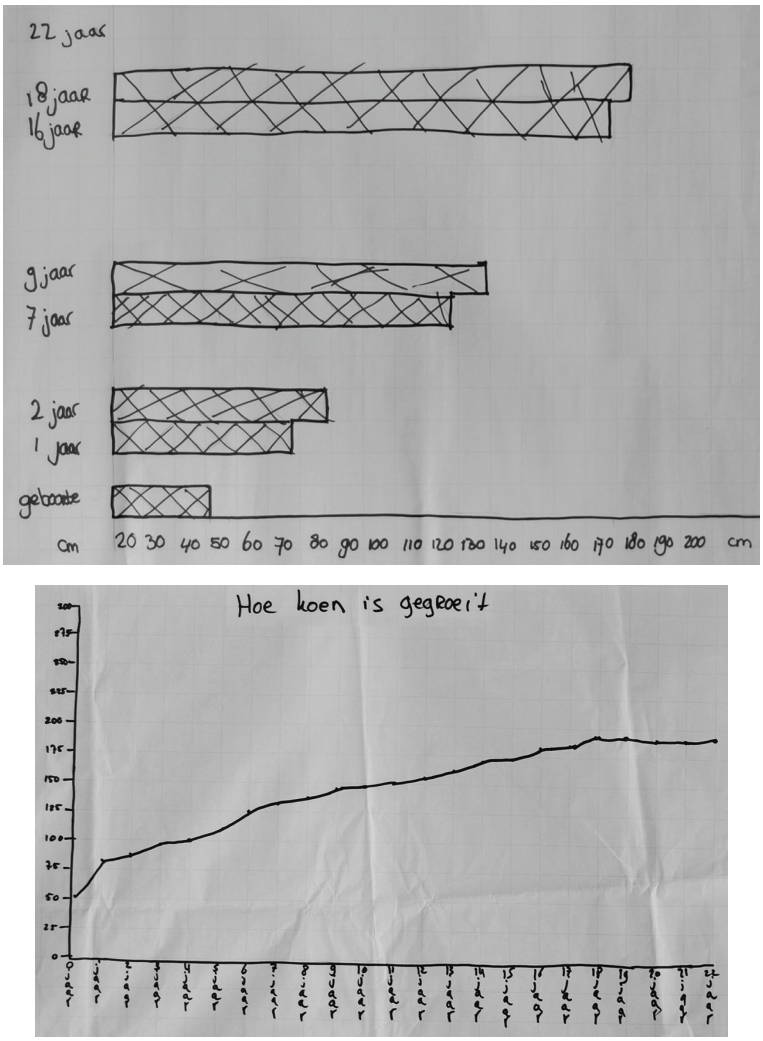


Figure 3 Posters on Koen's data set from the various small groups

Lesson 3

Exploring the context: whole-class discussion about the growth of a sunflower and introduction of measurement data in a table. To judge at a glance whether the sunflower will reach the height of three metres, the teacher discusses with the pupils how a line graph is constructed based on the measurement data on the board. This is done in the whole-class setting, but at the same time pupils also construct their own (similar) line graphs by carrying out all the different steps (e.g., drawing the axes). The line graph emerges by connecting the top points of lines that pupils draw for each measurement

(see Figure 4). The following words are central: *axis scale*, *step size*, *horizontal axis* and *vertical axis*. The key concept *constant* is introduced. At the end of the lesson pupils independently make descriptions along with their own line graphs.

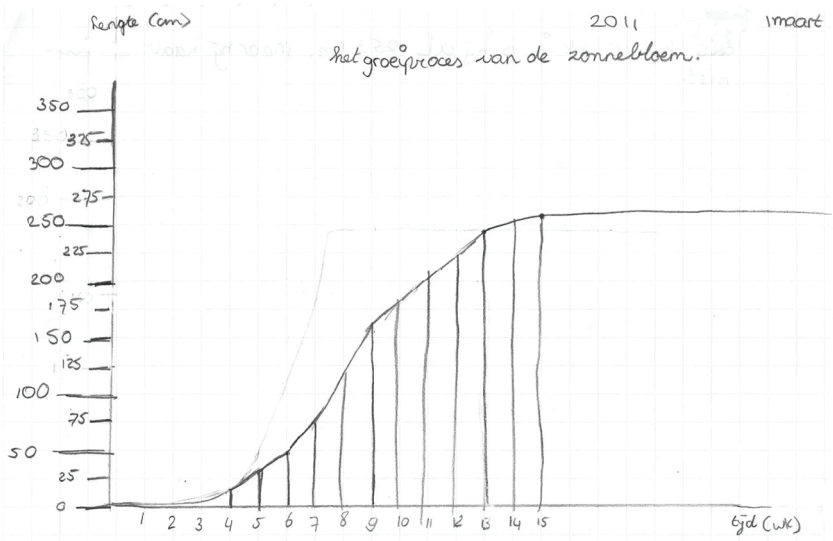


Figure 4 Growth of a sunflower; the emergence of a line graph

Lesson 4

Discussion about the steps that are needed to construct a line graph. During this discussion, concepts that have been already introduced are reinforced. The key concept *gradually* is introduced. Reflecting on line graph that represents the growth of a sunflower. Subsequently, several pupils' written utterances from their graph descriptions made during the previous lesson are discussed in PowerPoint. Pupils are asked: is this statement correct? As each statement is about one segment of the graph (see Figure 5) pupils come to realise that a line graph can be divided in different segments, which can be described separately. In the last instructional activity pupils explore the context of selling bags of chocolate Easter eggs and divide the line graph in segments. Subsequently, they verbally describe these segments, both in terms of reality and in terms of what the graph shows. The teacher guides this whole-class activity. The following words are central: *gradually*, *rise*, *descend*, *peak*, *trough*, *constant* and *maximum*.

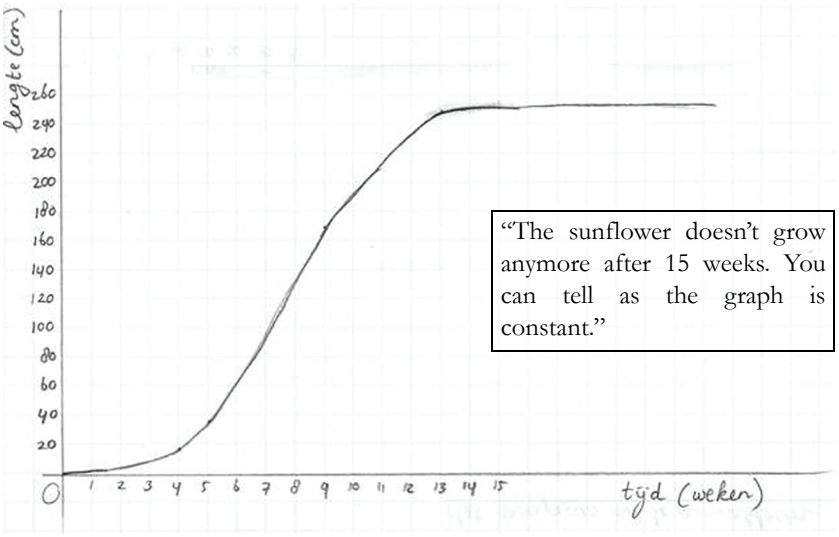


Figure 5 Exploring the graph and the meaning of *constant*

Lesson 5

Exploring a table with measurement data for the growth of giraffe Niek. Comparison of three different line graphs: what went wrong with two of these? Again the concepts of *step size* and *bias* are central. The correct line graph representing Niek's growth is the basis for discussion of several pupil utterances in PowerPoint. These utterances are anonymised by attributing them to an imaginary child, Piet Praatjens (Tom Talkative; see Figure 6). Each utterance is about one segment of the line graph and can be reformulated into more precise or more mathematical wording. This is done in whole-class discussion. Special attention is paid to temporal prepositions which either refer to a particular moment in time, represented by a point in the line graph (e.g., *at* the age of 6), or refer to a particular period in time, represented by a segment of the line graph (*between* 6 *and* 8). Subsequently, pupils make a verbal description of Niek's growth, supported by the teacher and a speaking frame. Attention is paid to the starting point and the end point of the line graph. Finally, pupils are asked to write down a description along with the line graph independently, supported by the same frame (which here functions as writing frame; see Figure 7).

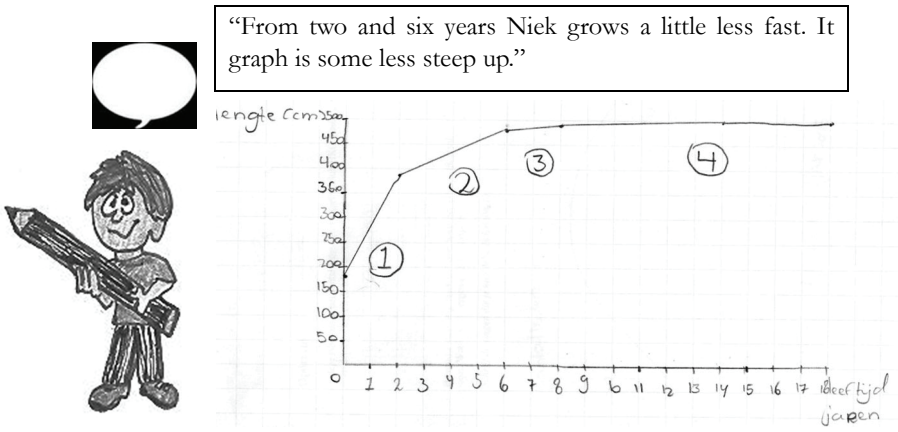
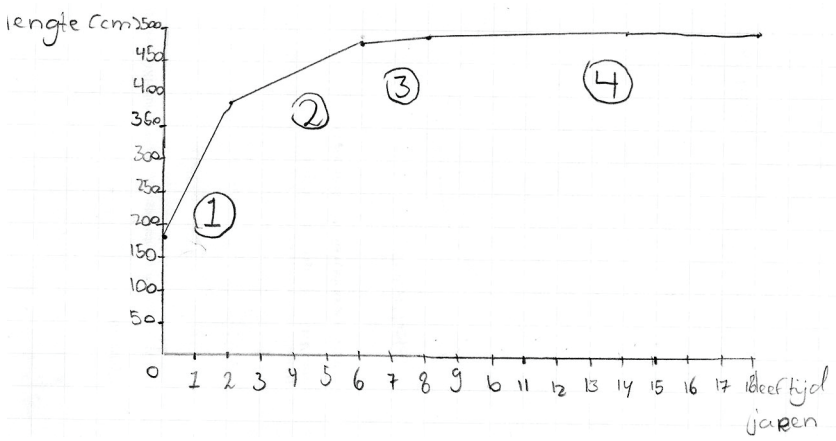


Figure 6 Tom Talkative (Piet Praatjens)



When Niek is born, he is ……

In his first years ……

You can tell as the graph ……

From the age of 2 onwards ……

The graph .....……..

After his 6th birthday …….

You can see .....……..

When Niek is about 9 years old ……

The graph ……

In the end Niek ……..

Figure 7 Example of speaking or writing frame

Worksheet: which name goes with each text?
Think of the name that belongs to each text and write it down:

- Narrative
- Instruction
- Description
- Report

Write down why you think this is the right name as well.

Text 1	*This is a:*
Yesterday our class went to the Efteling [amusement park]. In the Efteling there is a fairytale forest as well as many other great things, such as a coaster. I have been in there myself about eight times, which was much fun. At the end of the day we went for a pizza together. Mine was a Margherita.	*I think that because:* …… …… ……
Text 2	*This is a:*
Weigh 100 grams of sugar first. Also weigh 150 grams of flour. Put 150 grams of butter in a bowl. Then mix the butter and the eggs with it. Stir for about five minutes with a wooden ladle. Put the dough in the fridge for half an hour.	*I think that because:* …… …… ……
Text 3	*This is a:*
On a nice summer's day Peter went for a ride to the beach. On his way he met Fouad, with whom he planned to swim in the sea. When they were on their way, something strange happened. In the distance, on the road, there was some kind of an dark green odd thing. "What's this?!" Peter exclaimed. "You just wait here," Fouad said, "I will go and have a look."	*I think that because:* …… …… ……
Text 4	*This is a:*
From April first sports shop Van den Hoogenband little by little starts selling more swimwear. You can tell as the graph rises gradually. After 1 June the sports shop suddenly starts selling much more swimwear. The graph shows a steep rise.	*I think that because:* …… …… ……

Figure 8 Worksheet on genres

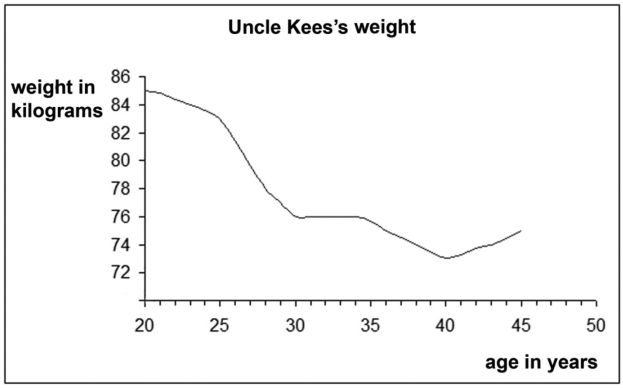
Lesson 6

Instructional activity in which four different genres are compared (see Figure 8): a *report*, a *narrative*, an *instruction* and a *description* (of a line graph). Whole-class discussion about features of each text type. The teacher makes explicit that pupils will learn to precisely make graph descriptions throughout the lessons. Also, the sense of this learning goal is discussed. In a subsequent instructional activity a line graph from a newspaper (representing migration of birds) is explored. The course of the line graph and changes in the graph's course are discussed. The line graph is divided in segments as a preparation for a writing activity. Next, pupils make a written line graph description independently supported by a writing frame for the first few sentences. In the supported part of this writing activity pupils only fill in temporal prepositions or phrases such as "descends gradually" and "rises quickly". The support provided also shows that each segment of the line graph can be described both in terms of reality and in terms of the graph's course (structure feature of the targeted genre).

Lesson 7

Exploration of a line graph representing Uncle Kees's weight. Subject-specific words are reinforced. The line graph is first divided in segments. Subsequently pupils receive a worksheet to practice the use of temporal prepositions (see Figure 9). Descriptions of the segments are mixed up so that pupils also practice in reading off the axes. Worksheets are discussed. Finally, pupils make a line graph description independently along with the graph (Figure 10 shows an example of text written by a pupil).

Worksheet 1: a graph description about uncle Kees's weight



Fill in the right words in the open spaces (….) in the sentences below. Choose from:

at - from … to - from … onwards - between

1. .....the age of 35……. ....the age of 40 Uncle Kees only loses a few kilos. He reaches his lowest weight.

2. .....the age of 20 Uncle Kees weighs 85 kilos.

3. .....the age of 40 …… Uncle Kees little by little puts on weight.

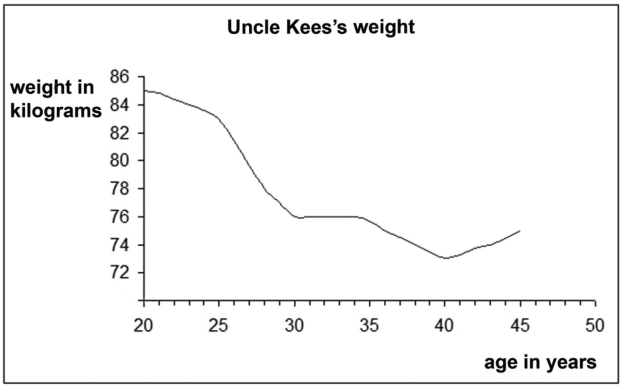
4.. .....the age of 45 Uncle Kees weighs almost 76 kilos.

5. .....the age of 30 and 35 Uncle Kees's weight hardly changes.

6. .....the ages of 26 and 30 Uncle Kees loses weight much quicker than before.

7. .....his 20th ……..his 25th he slowly starts to lose weight.

Figure 9 Worksheet on temporal prepositions



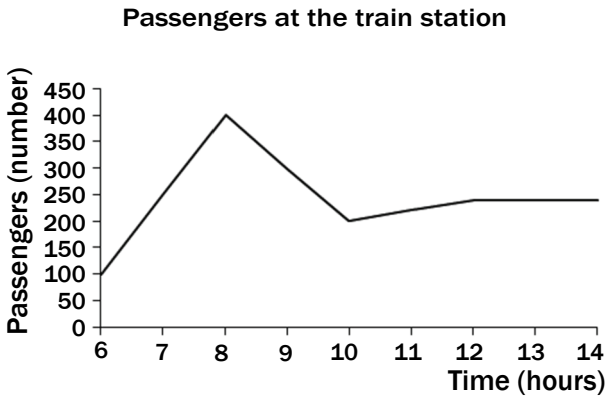
Uncle Kees is 85 kilos on his 20th birthday.
The graph has started.
From the age of 20 onwards Uncle Kees gets thinner and thinner.
The graph descends steeply!
From his 30st to his 35st Uncle Kees's weight stays the same.
The graph stays constant.
From his 35st to his 40st Uncle Kees gets thinner.
The graph descends gradually.
From his 45st onwards Uncle Kees puts on in weight.
The graph rises.

Figure 10 Example of written pupil text in the pedagogical genre of *interpretative description of a line graph* (The original handwritten text can be found in the Dutch appendices.)

Lesson 8

Utterances from the graph descriptions made during the previous lesson are discussed in PowerPoint. The main issue being discussed concerns the use of temporal prepositions. Subsequently, a new context is explored: passengers at the train station. Writing agreements made in previous lessons are written down on a flip-chart during this activity. These writing agreements include structure and linguistic features of the targeted pedagogical genre (see Chapter 3 in this thesis). Subsequently, a graph description is made in a whole-class process of joint construction, in which the teacher enacts scaffolding strategies. During this process the emerging graph description is shown on the white board. Finally, pupils independently make a line graph description along with the same graph (see Figure 11). In doing so, they can make use of the word list on the wall, but they do not receive support in the form of, for instance, a writing frame.

Worksheet: make a description that goes with this graph



Name:
Date:

.....

.....

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Figure 11 Worksheet: independent writing

Lesson 9

Pupils get back their graph descriptions from the previous lesson, and discuss and correct their descriptions in pairs. Subsequently, the writing agreements are centralised again and pupils also receive a writing plan (see Figure 12). Then a new line graph is explored, representing the sale of swimming trunks in a sports shop. By use of the writing plan several pupils make a verbal graph description in the whole-class setting. Structure and linguistic features of the genre are put central during this activity. Next,

pupils independently make a line graph description. In doing so, they can use both the word list and the writing plan. Finally, the teacher reflects on the lessons with the pupils, focusing on making, reading off and describing line graphs.

1. What is the graph about? Look at:

- the title;
- the axes;
- its course.

2. Divide the graph in segments.

3. Mark important points in the graph (starting point, end point, peaks, troughs).

4. Write down the first sentence: this one is about the starting point of the graph.

5. Now, for the first part of the graph, write:

- what happens in reality;
- what the graph's course shows.

6. Go on like this: write two sentences about each part of the graph. Also, write a sentence about each important point in the graph: what happens in reality?

7. Finish with a sentence about the end point of the graph.

Be aware:

- Use the word list on the wall!
- Write intelligibly: full sentences with capital letters and full stops.
- Ready? Done all steps?

Figure 12 Writing plan for line graph descriptions

Appendix B. One of the HLTs in the third teaching experiment (for lesson 7)

Mathematical and linguistic goals
• Pupils view a line graph as a representation involving different segments (stages) and can determine these segments (stages) independently. • Pupils develop a richer understanding of what points and segments of a line graph represent. • Pupils describe each segment in terms of reality and in terms of the course of the graph, using previously made writing agreements written on the whiteboard. • Pupils describe reality by deploying general academic language (e.g., his *weight decreases slowly*) and they describe the line graph by deploying subject-specific language (e.g., the *graph descends gradually*); in both cases they make use of the growing word list attached on the wall. • Pupils can relate words belonging to general academic language to words belonging to subject-specific language in terms of meaning (e.g., the relation between *decrease* and *descend*) • Pupils can correctly use temporal prepositions (*from…to*; *between...and*; *at*; *in*) for referring to points of the graph (moments in time) or segments of the graph (periods in time).
Starting points
Pupils have been introduced to subject-specific words (constant, axis, etc.). They are familiar with reading off information from line graphs and tables. Pupils have collaboratively constructed graphs themselves. They have difficulty interpreting changing direction in a graph. Pupils have been introduced to the idea that a graph can be divided into segments and that each segment can be described in terms of reality and in terms of direction of the graph. In most cases, pupils include the description of important points (peaks, troughs, starting point) when describing and interpreting line graphs. Some pupils still have difficulty using temporal prepositions to refer to periods or moments in time: *from...to*, *between...and*, *at*, *in*, etc.
Instructional activities
1. Teacher and pupils collectively divide a line graph representing Uncle Kees's weight into segments. 2. Pupils match sentences about Uncle Kees's weight (reality) and the course of the graph with the different segments of the graph, followed by a whole-class discussion. 3. Teacher explains temporal prepositions to the whole class, visually supported by using timelines; whole-class discussion of examples. 4. Pupils conduct a writing activity in which they fill in temporal prepositions in a writing frame containing a text about Uncle Kees's weight in the targeted pedagogical genre.
Assumptions about how the instructional activities support mental activities that lead to the mathematical goals
Ad 1) In discussing how to divide a line graph in different segments, pupils realise that changes in the course of the graph (direction) represent changes in reality. Ad 2) In matching sentences with segments of the graph, pupils' understanding of gradations of steepness in the graph is promoted. Ad 3) By using a timeline in visualising the use of temporal prepositions, which is related to the horizontal axis in the representation, pupils' mathematical understanding of moments and periods in time is promoted.

Ad 4) In consciously employing temporal prepositions in the activity of interpreting and describing a line graph, pupils develop conceptual understanding of points versus segments of the graph as well as of changes in the course of the graph.
Assumptions about how the instructional activities support mental activities that lead to the linguistic goals
Ad 1) In discussing how to divide a line graph in different segments, pupils prepare the activity of interpreting and describing a line graph. Ad 2) In matching pre-formulated sentences with segments of a line graph, pupils are provided with "modelled" genre sentences that will foster their genre proficiency. Furthermore, by providing pupils with given formulations, they can focus on and develop their understanding of attributing *both* an interpretation *and* a description to each segment of the graph. Ad 3) Pupils reinforce their knowledge and use of temporal prepositions. Ad 4) By actively using temporal prepositions in a meaningful context, pupils' (second) language development concerning this aspect of the pedagogical genre is promoted.

Appendix C. Scheme used for preinterview with the teacher before third teaching experiment

Reflection on own thoughts and actions

The following questions are about how you experienced your role in the teaching experiments conducted so far.

- What have you learned from participating in these two teaching experiments?
- What have you contributed yourself?
- What did you think about after the second teaching experiment?
- Did you talk to other people about the teaching experiments? About what in particular?
- If you reflect on your own actions: which things would you like to do as you have done up to now?
- If you reflect on your own actions: which things would you like to change in the next teaching experiment?
- During the second teaching experiment you increasingly made use of the "growing word list".
  - How did you manage that?
  - What are the benefits of this word list in your opinion?
  - How did you experience employing this word list in your teaching?

Scaffolding

- In what respect do you consider *scaffolding* something else than *help*?
- What do you think are characteristics of scaffolding?
- How would you define or characterise scaffolding if you were asked to explain it to other teachers who are unfamiliar with the concept?
- How do you value scaffolding in multilingual classrooms?
- Which episodes from the previous lesson series do you remember to contain scaffolding strategies that you consider successful or beneficial? To what extent do you consider such strategies to promote pupils' language development? To what extent do you consider such strategies to promote mathematical learning? What sort of language do you consider important when pupils learn about graphs?
- What would you like to know about pupils' mathematical starting levels related to reasoning about graphs (both in spoken as in written language)
- What do you concern necessary social norms to actually realise scaffolding in the classroom?

Collaboration

- What kind of collaboration do you hope for in the next teaching experiment?
- Are there any things you would like us to change in the teacher guides?
- Do you have anything to add to the things we have already discussed?

Appendix D. Examples of the teacher's written reflections on her enactment of scaffolding strategies

	Written reflection on enactment of scaffolding strategies after lesson 5	**Written reflection on enactment of scaffolding strategies after lesson 7**	**Written reflection on enactment of scaffolding strategies after lesson 9**
Reformulate pupils' utterances (spoken or written) into more academic wording	How do you say that? (activity 2) *from...to*	Very often.	Often.
Ask pupils to be more precise in spoken language or to improve their spoken language	Asked Moufid for meaning of constant because Mounir had explained it so beautifully just before.	After exploring the graph about uncle Kees I asked pupils to go through the graph and to use the words we had just practiced when telling about it. That was still a real effort!	Can you put this in a proper sentence? I realise that formulating more precisely occurs on two levels: content-wise and on the level of the sentence. That's what we are doing now.
Repeat correct pupil utterances	Yes, regularly I hear that children use concepts well. Then they get a turn or I say something like: "Yes, Moad has already said so: *step size*."	Sayeda: used *from...onwards* beautifully. Yassin in front of the whiteboard... (what an effort he makes!).	Yes. Also by asking if children can repeat that brilliant sentence.
Refer to features of the pedagogical genre (interpretative description of a line graph)	Activity 3 lent itself well for that.	I acted out structure feature reality/graph; that worked well. Is also observable in pupils' written work. So much better than last week! About which segment are we talking? How can you tell?	Often; activities lent themselves for that. Also aids like the writing plan, word list, poster *from...to*, words on the window.
Use gestures or drawings to support verbal reasoning	I had intended to support concepts as *constant* and *gradually* by gesturing with my back towards the classroom. Didn't do it.	Children point something out quickly and easily. Are more precise doing this. *Gradually* came along, in word and gesture! *Constant* is understood now!	Children now make these [gestures] as well and – like Youness – provide language with them: "Then nothing changes at all." [statement along with the gesture of *constant*].

	Written reflection on enactment of scaffolding strategies after lesson 5	Written reflection on enactment of scaffolding strategies after lesson 7	Written reflection on enactment of scaffolding strategies after lesson 9
Remind pupils (by gesturing or verbally) to use a designed scaffold (i.e. word list or writing plan) as a supporting material	Word list; last week.	Much mathematical language is used and you can also see children look at it [teacher refers to word list on the wall].	Often; well integrated in the lesson. One also notices that children use these [designed scaffolds]. Hamid really looked for *gradually* [on the word list]. Lovely to see.
Ask pupils how written text can be produced or improved	Activity 2. In retrospect the sentences were too inarticulate. One also notices that children change the sentence and want to keep too many words in doing so. That makes it very difficult to make adjustments (for example Ahida or Bela).	The words *from...to* etcetera have been intensively discussed. It was good that I could point out these words again and again, with drawings and all that. Is clarifying. Semi also copied those drawings on his sheet! Children don't mind us to chew on those words for so long [teacher means something like "that we get back to those words so often"]. Children correct each other as well now! 1x some laughter; was gone soon. (I kind of understood the joke anyway.)	Yes, activity 2 and sometimes during activity 1.

The content of the written reflections is unchanged. Only a few spelling errors have been corrected and in some places punctuation has been added or corrected for the sake of legibility. The core concepts the teacher refers to have been italicised to improve legibility. Abbreviations (chldn.) have been written in full (children). Pupil names have been made up to protect anonymity. There are occasional clarifications between square brackets.

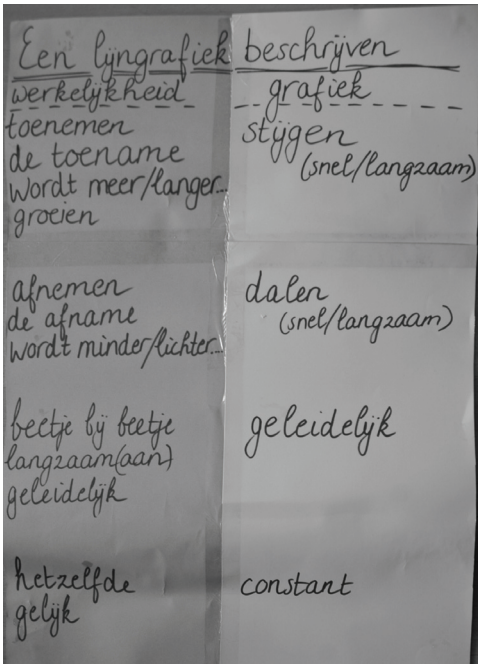
Appendices in Dutch

Appendix A. Lesbeschrijvingen en voorbeelden van lesactiviteiten en leerlingwerk

Deze beschrijvingen zijn achteraf geformuleerd voor de lezer van dit proefschrift, om een idee te geven van hoe de lessen eruit hebben gezien. Ze vormen geen deel van de HLT's of van de docentenhandleiding.

Les 1

De leerlingen maken kennis met de (externe) leerkracht en bespreken de aard van de taal-rekenlessen: spreken en schrijven over rekenen. Introductie van de woordenlijst (Figuur 1) waarop school- en vaktaalwoorden zullen worden geschreven in de loop van de lessen. Introductie van de social norms die nodig zijn om taal-rekenlessen mogelijk te maken, bijvoorbeeld: we luisteren naar elkaar; we willen elkaar begrijpen. Lesactiviteit over de groei van Koen waarin leerlingen na discussie over een set meetgegevens (Figuur 2) de vraag krijgen voorgelegd: "Kun je een plaatje bedenken waarin ik de groei van Koen beter kan volgen?" In antwoord op de vraag maken de leerlingen zelf een representatie. Vervolgens kiezen ze in subgroepjes de "beste" representatie van Koens groei (één per subgroepje) en zetten die op een poster. Introductie van woorden als: *lengte*, *meetgegevens*, *tabel* en *groei*(*proces*).



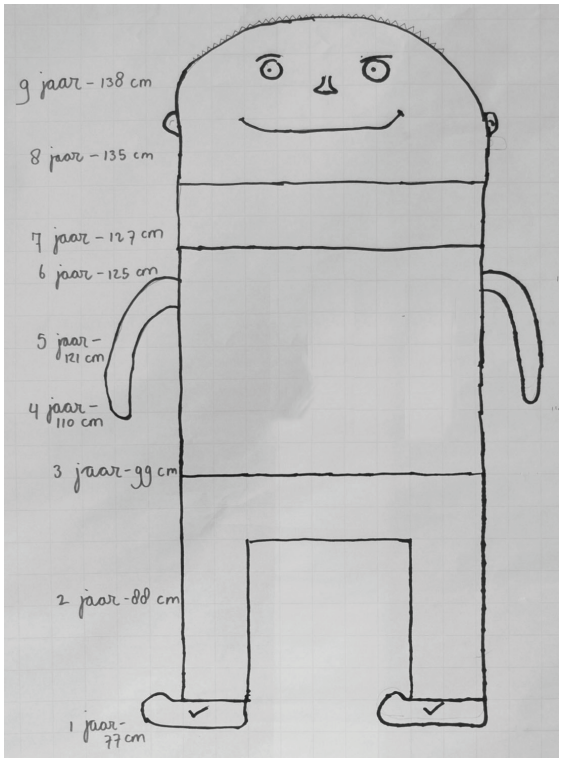
Figuur 1 Woordenlijst aan het einde van het derde onderwijsexperiment

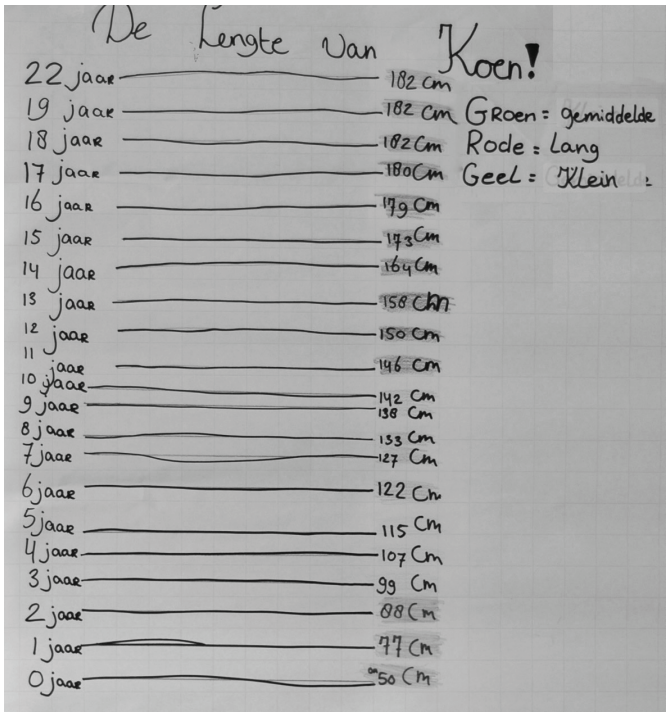
22 jaar	182 cm
18 jaar	182 cm
16 jaar	179 cm
9 jaar	138 cm
7 jaar	127 cm
2 jaar	88 cm
1 jaar	77 cm

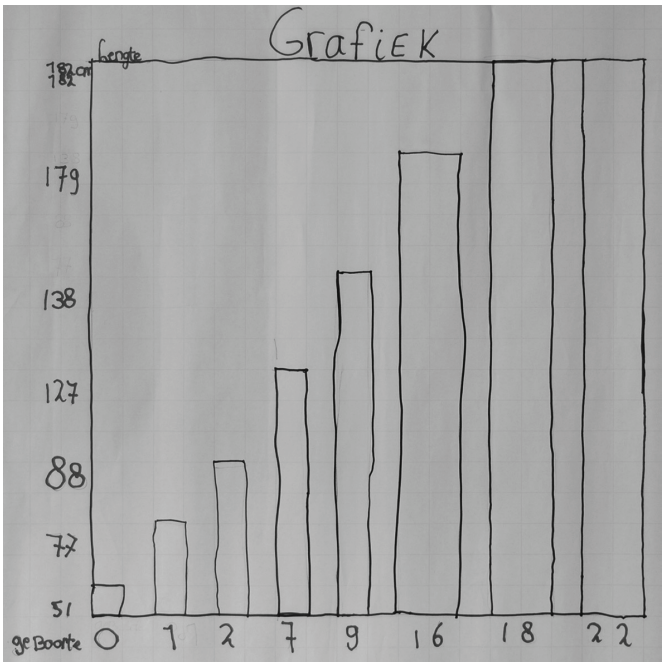
Figuur 2 Dataset van Koens lengte door de jaren heen

Les 2

Leerlingen bereiden posterpresentaties voor in subgroepjes. Elk groepje geeft vervolgens een korte presentatie van de "eigen representatie" (zie voorbeelden in Figuur 3), gevolgd door klassikale discussie. In het vergelijken van verschillende representaties komen onder andere de volgende woorden naar voren: *lijngrafiek*, *staafgrafiek*, *vertekening*, *verloop*, *horizontale as*, *verticale as*. De lijngrafiek komt naar voren als de meest geschikte representatie bij de gegeven data.




De Lengte van Koen!
22 jaar 182 cm
19 jaar 182 cm
18 jaar 182 cm
17 jaar 180 cm
16 jaar 179 cm
15 jaar 173 cm
14 jaar 164 cm
13 jaar 158 cm
12 jaar 150 cm
11 jaar 146 cm
10 jaar 142 cm
9 jaar 138 cm
8 jaar 133 cm
7 jaar 127 cm
6 jaar 122 cm
5 jaar 115 cm
4 jaar 107 cm
3 jaar 99 cm
2 jaar 88 cm
1 jaar 77 cm
0 jaar 50 cm
Groen = gemiddelde
Rode = Lang
Geel = Klein


Grafiek
lengte
182 cm
182
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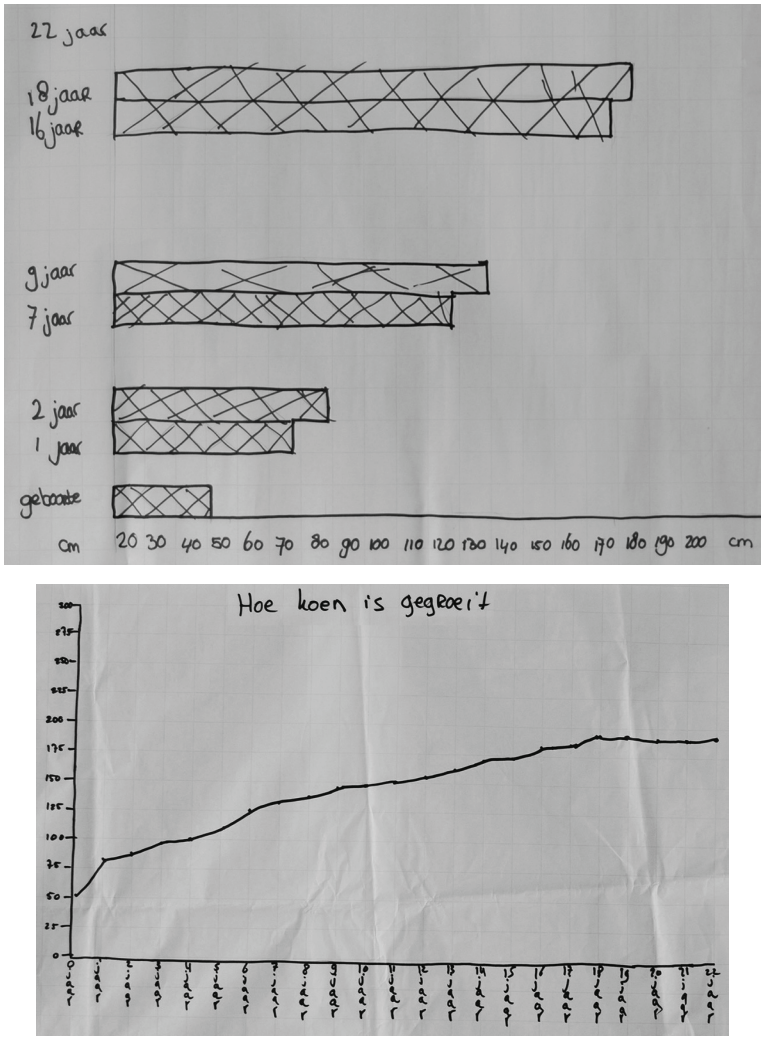
51
geboorte 0 1 2 7 9 16 18 22

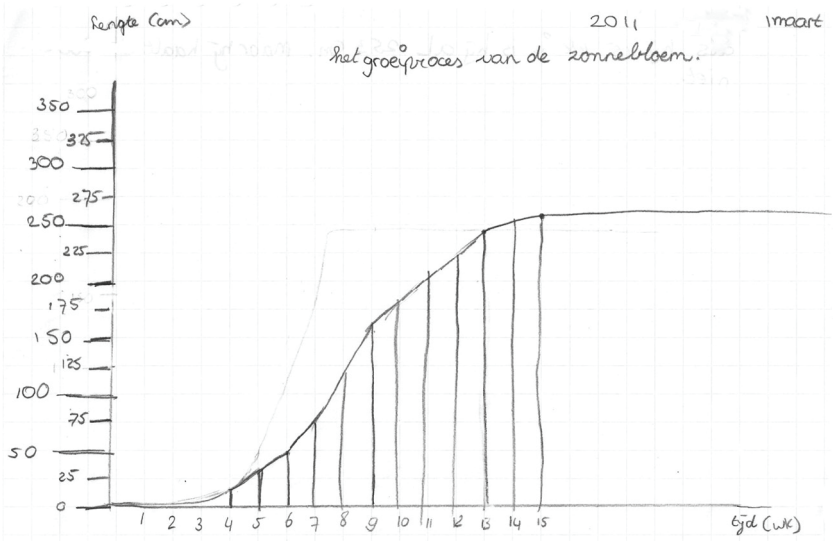


Figuur 3 Posters van de verschillende subgroepen

Les 3

Oriëntatie context: klassikale discussie over de groei van een zonnebloem; introductie van meetgegevens in een tabel. Om in 1 oogopslag te kunnen zien of de zonnebloem de 3 meter haalt, wordt op basis van de meetgegevens klassikaal een lijngrafiek geconstrueerd. Leerlingen doen alle stappen individueel mee en maken op die manier ook zelf een lijngrafiek. De lijngrafiek "ontstaat" daarbij uit losse metingen die elk met een streep (later met een punt) worden weergegeven voordat ze worden verbonden tot een lijngrafiek (zie Figuur 4). Leerlingen maken (opnieuw) kennis met begrippen als:

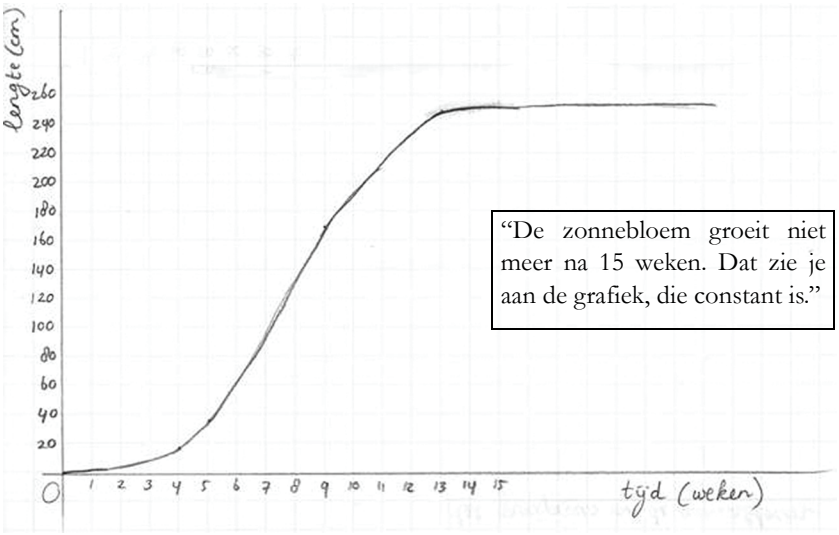
asindeling, *stapgrootte*, *horizontale as* en *verticale as*. Het begrip *constant* wordt geïntroduceerd. Leerlingen maken tot slot zelf een schriftelijke beschrijving bij hun eigen zonnebloemgrafiek.



Figuur 4 Groei van de zonnebloem; het ontstaan van een lijngrafiek

Les 4

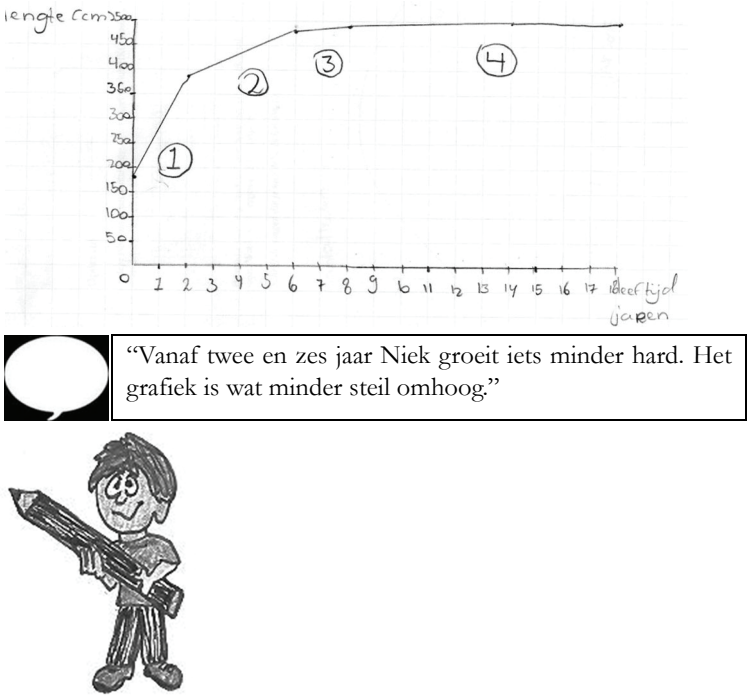
Herhaling van de verschillende stappen die nodig zijn om een lijngrafiek te construeren; herhalen van eerder geïntroduceerde (vaktaal)begrippen en introductie van nieuwe begrippen, bijvoorbeeld *geleidelijk*. Terugblikken op de ontstane zonnebloemgrafiek aan de hand van vragen. In powerpoint worden vervolgens klassikaal beweringen besproken die leerlingen in hun beschrijvingen (einde vorige les) hebben gedaan. Bij elke uitspraak (zie Figuur 5) wordt aan de klas de vraag voorgelegd "klopt deze uitspraak?". Omdat elke uitspraak over één stuk van de grafiek gaat, realiseren leerlingen zich dat een grafiek uit "stukken" bestaat die afzonderlijk beschreven kunnen worden. In de laatste activiteit verkennen leerlingen een nieuwe context en een nieuwe grafiek (verkoop van zakken paaseitjes), verdelen de grafiek klassikaal "in stukken" en oefenen vervolgens met het mondeling beschrijven van een lijngrafiek, ondersteund door de docent. Daarbij komen begrippen als *geleidelijk*, *stijgen*, *dalen*, *piek*, *constant* en *maximum* aan bod.



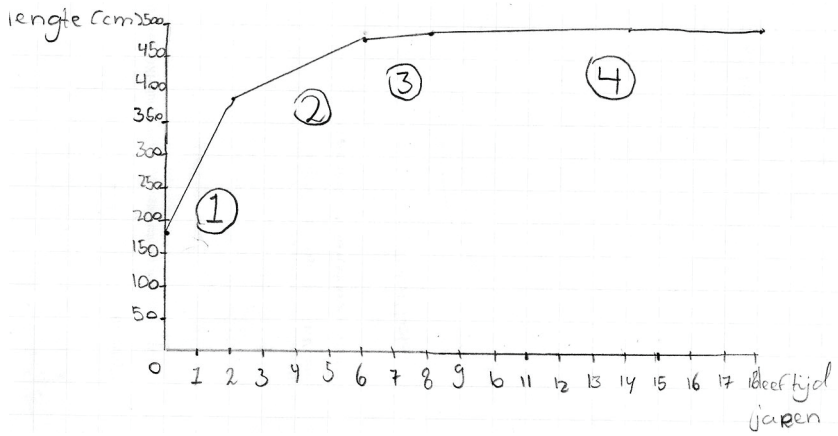
Figuur 5 Verkennen van de grafiek en de betekenis van "constant"

Les 5

Oriëntatie context: bespreken van een tabel met groeigegevens (de groei van giraf Niek). Vergelijking van drie verschillende lijngrafieken bij deze gegevens: wat is er mis gegaan bij twee van de drie grafieken? Opnieuw komen stapgrootte en vertekening aan de orde. Aan de hand van een goede lijngrafiek die de groei van Niek representeert (op flipovervel) worden vervolgens verschillende leerlinguitspraken besproken in powerpoint. Elke uitspraak gaat steeds over één stukje van de lijngrafiek en zou preciezer of "wiskundiger" geformuleerd kunnen worden. Klassikaal worden deze uitspraken van de fictieve jongen "Piet Praatjens" verbeterd (Figuur 6). Er wordt aandacht besteed aan woorden als *van...tot*, *vanaf*, *tussen...en* (*temporal prepositions*). Daarbij wordt onderscheid gemaakt tussen punten in de grafiek (momenten in de werkelijkheid) en segmenten ("stukjes") van de grafiek (periodes in de werkelijkheid). Vervolgens maken leerlingen en docent met behulp van een spreekkader een verbeterde mondelinge beschrijving van de groei van giraf Niek. Er wordt aandacht besteed aan het begin- en eindpunt van de grafiek. Tot slot maken de leerlingen individueel een schriftelijke beschrijving, ondersteund door hetzelfde kader (nu gebruikt als schrijfkader; Figuur 7).



Figuur 6 Klassikale bespreking van leerlingtaaluitingen uitgesproken door "Piet Praatjens"



Als Niek geboren wordt, is hij……

De eerste paar jaar……...……

Dat zie je aan de grafiek, die ……

Vanaf zijn tweede jaar groeit ……

De grafiek .....……..

Na zijn zesde …….....…….

Dat zie je aan .....……..

Als hij ongeveer 9 jaar oud is .....……

De grafiek……...……

Uiteindelijk wordt Niek ....…..……..

Figuur 7 Voorbeeld van een spreek- of schrijfkader

Les 6

Activiteit waarin verschillende genres met elkaar vergeleken worden (Figuur 8): verslag, verhaal, instructie, beschrijving (van een lijngrafiek). Klassikale discussie over kenmerken van elke tekstsoort (genre). Er wordt expliciet gemaakt dat de leerlingen in deze lessen zullen leren om zo precies mogelijk een grafiek te beschrijven. Klassikaal wordt bediscussieerd wat leerlingen daaraan zouden hebben. Vervolgens wordt een nieuwe lijngrafiek (afkomstig uit de krant) verkend over migratie van wulpen. Hierbij worden schooltalige en vaktalige kernbegrippen herhaald. Het verloop van de grafiek wordt besproken en daarbij de veranderingen die uit het verloop zijn af te lezen. Ter voorbereiding op het beschrijven van de grafiek wordt deze klassikaal in stukken verdeeld. Vervolgens maken leerlingen op een werkblad een beschrijving bij de wulpengrafiek. Voor de eerste stukken van de grafiek krijgen ze daarbij steun van een

Werkblad: welke naam past bij welke tekst?
Schrijf bij elke tekst de naam op die er volgens jou bij hoort:

- Verhaal
- Instructie
- Beschrijving
- Verslag

Schrijf ook op waarom je dat denkt.

Tekst 1	*Dit is een:*
Gisteren zijn we met de klas naar de Efteling geweest. In de Efteling hebben ze een sprookjesbos en er zijn ook nog allemaal andere leuke dingen, bijvoorbeeld de achtbaan. Ik ben zelf wel acht keer in de achtbaan geweest, dat was erg leuk. Aan het eind van de dag zijn we met z'n allen pizza gaan eten. Ik had een pizza Margherita.	*Dat denk ik omdat:* …… …… ……
Tekst 2	*Dit is een:*
Weeg eerst 100 gram suiker af. Weeg ook 150 gram bloem af. Doe 150 gram boter in een kom. Meng er vervolgens de boter en suiker doorheen. Roer 5 minuten lang met een houten lepel. Zet het beslag dan een halfuur in de koelkast.	*Dat denk ik omdat:* …… …… ……
Tekst 3	*Dit is een:*
Op een mooie zomerdag stapte Peter op zijn fiets op weg naar het strand. Onderweg ontmoette hij Fouad, met wie hij een frisse duik in de zee zou gaan nemen. Toen ze nog niet halverwege hun huis en het strand waren, gebeurde er iets heel vreemds. In de verte, op de weg, zagen ze een raar donkergroen ding liggen. "Wat zullen we nou hebben?' zei Peter geschrokken. 'Wacht jij maar hier,' zei Fouad, 'ik ga wel even kijken".	*Dat denk ik omdat:* …… …… ……
Tekst 4	*Dit is een*
Vanaf 1 april verkoopt sportwinkel Van den Hoogenband langzaamaan meer zwembroeken. Dat zie je aan de grafiek, die geleidelijk stijgt. Na 1 juni gaat de sportwinkel opeens veel meer zwembroeken verkopen. De grafiek laat een snelle stijging zien.	*Dat denk ik omdat:* …… …… ……

Figuur 8 Werkblad over genres

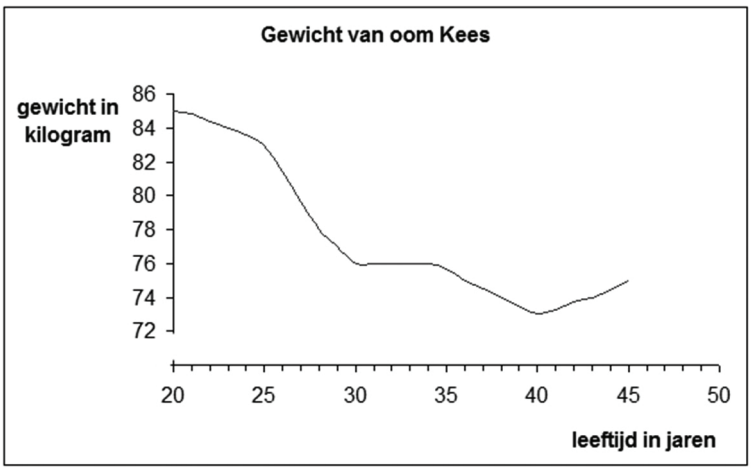
schrijfkader; ze vullen zelf alleen de *temporal prepositions* in óf frases als "stijgt", "stijgt langzaam", "daalt snel" enzovoort. Door het schrijfkader zien leerlingen (opnieuw) dat voor elk stuk van de grafiek zowel een beschrijving van de werkelijkheid als een

beschrijving van de grafiek wordt gemaakt (genrekenmerk). De laatste stukken van de wulpengrafiek beschrijven de leerlingen zelfstandig, zonder steun.

Les 7

Klassikaal wordt eerst een lijngrafiek over het gewicht van oom Kees verkend. Daarbij worden vaktalige begrippen herhaald (bijvoorbeeld *verloop*). De grafiek wordt in stukken verdeeld. Vervolgens krijgen leerlingen een werkblad waarop ze oefenen met de *temporal prepositions* (Figuur 9). De stukken van de grafiek staan door elkaar en daarmee oefenen ze ook in het aflezen van de assen. De werkbladen worden besproken. Leerlingen maken tot slot individueel en zelfstandig een beschrijving bij de grafiek (zie Figuur 10 voor een voorbeeld van een leerlingtekst).

Werkblad 1: een beschrijving over het gewicht van oom Kees

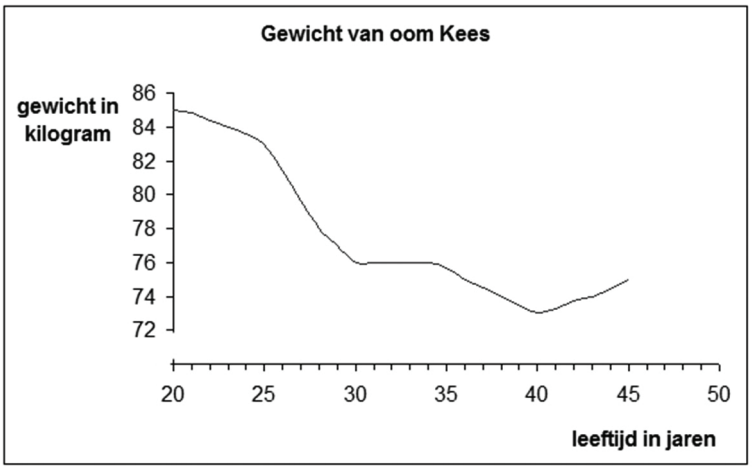


Vul het juiste woord in op de open plekken (.....) in de zinnen hieronder. Kies uit:

vanaf - op - van - tussen

1. .....zijn 35ste tot zijn 40ste valt oom Kees nog een paar kilo af; hij bereikt nu zijn laagste gewicht.
2. .....zijn 20ste weegt oom Kees 85 kilo.
3.....zijn 40ste komt oom Kees beetje bij beetje aan.
4. .....zijn 45ste weegt oom Kees bijna 76 kilo.
5. .....zijn 30ste en zijn 35ste verandert het gewicht van oom Kees nauwelijks.
6. .....zijn 26ste valt oom Kees een stuk sneller af dan daarvoor.
7. .....zijn 20ste begint hij langzaamaan af te vallen.

Figuur 9 Werkblad over *temporal prepositions*



1) Oom Kees is op zijn 20ste 85 kilo zwaar.
De grafiek is begonnen

2) Vanaf zijn 20ste word oom kees steeds dunner en dunner
De grafiek daalt snel!

3) Van zijn 30ste tot zijn 35 ste blijft Oom Kees even zwaar
De grafiek blijft constant

4) Van zijn 35ste tot zijn 40ste word Oom Kees weer iets dunner
de grafiek daalt geleidelijk

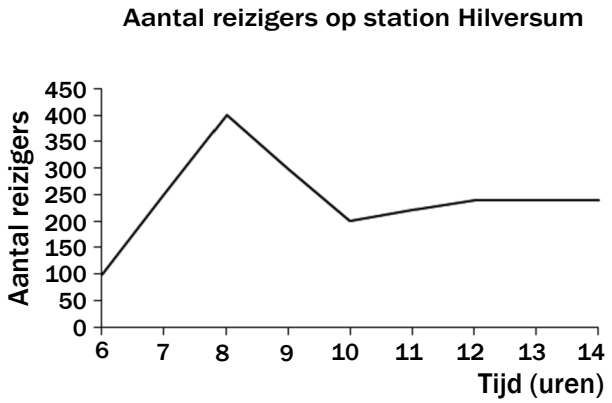
5) Vanaf zijn 45ste word Oom Kees weer dikker.
De grafiek stijgt

Figuur 10 Voorbeeld van doeltekst door een leerling

Les 8

De grafiekbeschrijvingen van leerlingen uit les zeven worden besproken in powerpoint: er wordt steeds één zin besproken uit een beschrijving waarbij de aandacht vooral uitgaat naar het onderscheid tussen momenten (punten in de grafiek) en periodes (segmenten in de grafiek) en de *temporal prepositions* die daarvoor gebruikt kunnen worden. Vervolgens wordt de grafiek "reizigers op station" verkend. Schrijfafspraken die de afgelopen lessen gemaakt zijn, worden tijdens deze activiteit op een flipovervel geschreven. Deze schrijfafspraken bevatten talige en structuurkenmerken van het *pedagogical genre* (zie hoofdstuk 3 in dit proefschrift).Vervolgens wordt een gezamenlijke grafiekbeschrijving gemaakt (*joint construction*), waarbij de docent de leerlingen in klassikale interactie talige ondersteuning biedt. De grafiekbeschrijving verschijnt op het digibord. Tot slot maken de leerlingen individueel een beschrijving bij dezelfde reizigersgrafiek (Figuur 11), met hulp van de woordenlijst aan de muur, maar zonder steun van bijvoorbeeld een schrijfkader.

Werkblad: maak een beschrijving bij deze grafiek



Naam:
Datum:

.....

.....

.....

.....

.....

.....

Figuur 11 Werkblad: zelfstandig schrijven

Les 9

Leerlingen krijgen hun grafiekbeschrijvingen uit de vorige les terug en bespreken en verbeteren hun beschrijvingen in tweetallen. Vervolgens wordt op de schrijfafspraken teruggekomen en krijgen leerlingen een stappenplan voor het schrijven (Figuur 12). Daarna wordt een nieuwe grafiek verkend, over de verkoop van zwembroeken in een sportwinkel. Aan de hand van het stappenplan wordt vervolgens door verschillende leerlingen een mondelinge grafiekbeschrijving gemaakt. Daarbij komen de talige en structuurkenmerken van het *pedagogical genre* weer aan bod. Leerlingen maken vervolgens zelf een schriftelijke grafiekbeschrijving, waarbij ze gebruik mogen maken van de woordenlijst en het stappenplan. Tot slot wordt teruggeblikt op de lessenserie, waarbij er aandacht is voor het maken, het aflezen en het beschrijven van lijngrafieken.

1. Waar gaat de grafiek over? Bekijk:

- de titel;
- de assen;
- het verloop.

2. Verdeel de grafiek in stukken.

3. Markeer de belangrijke punten (begin, eind, pieken, dalen) in de grafiek.

4. Schrijf de eerste zin op: deze gaat over het beginpunt van de grafiek.

5. Schrijf nu over het eerste *stukje* van de grafiek:

- wat er in het echt gebeurt;
- wat de grafiek laat zien.

6. Ga zo verder: schrijf over elk stukje grafiek twee zinnen. Schrijf ook over elk belangrijk punt een zin: wat gebeurt er in het echt?

7. Eindig met een zin over het eindpunt van de grafiek.

Let op:

- Gebruik de woordenlijst!
- Schrijf begrijpelijk: hele zinnen met hoofdletter en punt.
- Klaar? Alle stappen gedaan?

Figuur 12 Stappenplan voor het beschrijven van een lijngrafiek

	Geschreven docentreflectie op wel/niet geboden strategieën na les 5	Geschreven docentreflectie op wel/niet geboden strategieën na les 7	Geschreven docentreflectie op wel/niet geboden strategieën na les 9
Herformuleren van leerling-uitingen (gesproken of geschreven)	Hoe zeg je dat? (Opdracht 2) *van ... tot*	Heel vaak.	Vaak.
Leerlingen vragen om preciezer te formuleren (in gesproken taal) of om gesproken taal te verbeteren	Moufid gevraagd naar *constant* omdat Mounir hem dat daarvoor zo mooi had uitgelegd.	Na inventarisatie grafiek oom Kees vroeg ik leerlingen de grafiek te doorlopen en bij het vertellen gebruik te maken van de woorden die we net geoefend hadden. Dat kostte nog steeds veel moeite!	Kun je er een mooie zin van maken? Ik realiseer me dat het preciezer formuleren op twee lagen plaatsvindt: inhoudelijk en op zinsbouwniveau. Daar zijn we nu meer mee bezig.
Correcte, voorbeeldmatige taaluitingen van leerlingen herhalen	Ja, regelmatig hoor ik nu dat kinderen begrippen goed gebruiken. Ze krijgen dan ook een beurt of ik zeg zoiets als: "Ja, Moad zegt het al: *stapgrootte*."	Sayeda: gebruikte prachtig vanaf. Yassin voor het bord... (wat doet hij hard zijn best!).	Ja. Ook door te te vragen of kinderen zelf die topzin nog eens willen herhalen.
Verwijzen of herinneren aan talige of structuurkenmerken van de doeltekst	Onderdeel 3 leende zich daar goed voor.	Structuurkenmerk echt/grafiek heb ik nu uitgebeeld; dat werkte goed. Zie je ook terug in het leerlingwerk. Zo veel beter dan vorige week! Over welk stuk gaat dit? Hoe zie je dat?	Veel; opdrachten leenden zich hier ook voor. Ook de hulpmiddelen zoals stappenplan, woordenlijst, poster *van…tot*, woorden op het raam.

	Geschreven docentreflectie op wel/niet geboden strategieën na les 5	Geschreven docentreflectie op wel/niet geboden strategieën na les 7	Geschreven docentreflectie op wel/niet geboden strategieën na les 9
Gebaren gebruiken ter ondersteuning van een verbale redenering over een grafiek	Had me voorgenomen begrippen als *constant* en *geleidelijk* met gebaar en rug naar de klas te ondersteunen. Niet gedaan.	Kinderen wijzen nu snel en makkelijk iets aan. Zijn daar ook preciezer in. *Geleidelijk* kwam weer langs, in woord en gebaar! *Constant* is helder!	Kinderen maken die [gebaren] nu ook en – zoals Youness – geven daar meteen taal bij: "Dan verandert er helemaal niets." [uitspraak bij het gebaar *constant*].
Leerlingen herinneren aan het gebruik van "designed scaffolds", zoals de woordenlijst of een stappenplan	Woordenlijst; vorige week.	Er wordt veel rekentaal gebruikt en je ziet kinderen daar ook naar kijken [leerkracht refereeert aan woordenlijst op de muur].	Veel; goed geïntegreerd in de les. Je ziet ook dat kinderen dit [*designed scaffolds*] gebruiken. Hamid keek echt en zocht naar *geleidelijk*. Mooi om te zien.
Leerlingen vragen hoe geschreven taal kan worden geproduceerd of verbeterd	Opdracht 2. De zinnen waren - achteraf - soms te krom. Je merkt ook dat kinderen de zin veranderen waarbij ze te veel woorden willen laten staan, zodat veranderen erg lastig is (bijvoorbeeld Ahida of Bela).	De woorden *vanaf…tot* enzovoort intensief besproken. Mooi was dat ik de woorden ook weer steeds kon aanwijzen, met tekening en al. Werkt verhelderend. Semi heeft die tekeningen ook overgenomen op zijn blad! Kinderen vinden het geen punt dat we zo lang op die woorden kauwen. Kinderen verbeteren elkaar nu ook! 1x wat gelach; was snel weg. (Ik snapte het gelach/de grap ook wel.)	Ja, opdracht 2 en heel soms bij opdracht 1.

De inhoud van de geschreven reflecties is onveranderd. Slechts een enkele spelfout is gecorrigeeerd en op een paar plekken zijn leestekens toegevoegd of gecorrigeerd voor de leesbaarheid. De kernbegrippen waarnaar de docent verwijst, zijn gecursiveerd voor de leesbaarheid. Afkortingen (kdn) zijn voluit geschreven (kinderen). Leerlingnamen zijn gefingeerd. Een enkele keer staat er een toelichting tussen vierkante haken.

Dankwoord

Dolly, mijn eerste woorden van dank komen vanzelfsprekend jou toe. Op het moment dat Arthur thuis kwam en me vertelde dat er een promotiebaan ("iets met taal") aan het FI zou komen, liep ik in eerste instantie niet zo hard. Abel was kort daarvoor geboren en ik was net met een nieuwe baan begonnen, en ik vond het *all too much* om ook nog over een leven als promovendus na te moeten denken. Toch, ook een beetje uit nieuwsgierigheid, ben ik gaan solliciteren. Tijdens dat gesprek maakte je zo'n sympathieke, welbespraakte, humoristische en geïnspireerde indruk op me dat ik direct voor me zag hoe leuk een promotietraject onder jouw begeleiding zou zijn. De beslissing was snel genomen toen je me opbelde en me vertelde dat ik de baan had gekregen. Vanaf kort daarna zou ik vijf en een half jaar onderzoek doen naar het bieden van talige ondersteuning in meertalige rekenklassen.

Het eerste jaar heb je me alle ruimte gegeven om me in te lezen in het onderwerp, ideeën te poneren en weer te verwerpen, een geschikt rekendomein te kiezen en exploratief onderzoek te doen. Ook leerde je me veel over ontwikkelingsonderzoek en realistisch reken-wiskundeonderwijs, en ik genoot ervan om de colleges bij te wonen die je hierover aan de Indonesische studenten gaf. We spraken elkaar vanaf het begin vaak meerdere keren per week en we emailden in sommige periodes dagelijks. Over het boek *Scaffolding language, scaffolding learning* van Pauline Gibbons was je heel enthousiast en zei je in het eerste jaar een keer: "Zoiets ga jij ook doen, maar jij gaat het vakspecifiek uitwerken voor rekenen-wiskunde." Dat heb ik blijkbaar vrij letterlijk genomen, want het werk van Pauline Gibbons is heel richtinggevend in mijn onderzoek geweest en *scaffolding* is inderdaad een kernconcept geworden. En na dat eerste jaar werd Adinda geboren.

Aan het einde van mijn zwangerschapsverlof belde je me op en vroeg hoe het ging. Ik zei: "Goed, en volgende week ga ik weer aan het werk." Waarop jij zei: "Ben je daar wel aan toe; is dat niet wat te vroeg?" Waarop ik zei: "Maar ik heb toch gewoon een baan? Mijn verlof loopt af en dus ga ik volgende week weer aan het werk." Waarop jij reageerde: "Doe vooral rustig aan en kom alleen als je ook weer een beetje zin hebt." Zo typerend voor jouw menselijkheid. En het grappige is: het maakte dat ik er meteen weer zin in had. Alles kwam in volle vaart vanaf mijn terugkeer. We hebben samen veel tijd gestoken in het doordenken van de drie onderwijsexperimenten, het ontwerpen van lessen, het bekijken van lesfragmenten en het reflecteren op de experimenten. In gesprek met jou ontstonden cruciale ideeën. En soms concludeerden we dan tevreden aan het einde van zo'n gesprek: "Dit was weer een mooi staaltje *interthinking*."

De laatste twee jaar stonden in het teken van schrijven. Je hebt me gesteund in de onafhankelijkheid waar ik als schrijver behoefte aan had. Je leverde grondig commentaar

op mijn teksten. En je stond altijd open voor onverwachte ideeën ("een conceptueel artikel over *whole-class scaffolding*? Klinkt interessant"). Ook organiseerden we symposia met mensen die jij al langer kende (Ed Elbers, Neil Mercer en anderen) of ontmoet had (Janneke van de Pol). Mede daardoor maakt nu een van de artikelen in dit proefschrift deel uit van een *special issue* over *scaffolding*, iets waar we het al in een vroeg stadium over hadden. De laatste jaren hebben we samen conferenties bezocht. Niets was vertrouwder dan jou op de eerste rij te zien zitten bij een presentatie. En natuurlijk had ik nooit gedacht dat ik met jou ook nog zo veel lol zou hebben. Het heeft het voor mij mogelijk gemaakt om deze o-zo-serieuze baan vol te houden én leuk te blijven vinden tot het allerlaatste moment. Dolly, je bent fantastisch. Ontzettend bedankt. En ik kijk er enorm naar uit dat we nu "officieel" vriendinnen kunnen worden.

Mijn dank gaat ook uit naar Koeno en Jan, mijn promotoren, die beiden vanaf het sollicitatiegesprek bij mijn onderzoek betrokken zijn geweest. Tijdens dit gesprek verwachtte ik van Jan een ingewikkelde vraag over reken-wiskundedidactiek. In plaats daarvan zei hij: "Ik zie op je cv dat je al jaren aanvoerder bent in orkesten en ik ben benieuwd hoe die ervaring van pas zou kunnen komen." Van Koeno verwachtte ik ook een ingewikkelde vraag over reken-wiskundedidactiek. Maar hij zei: "Je kunt blijkbaar goed schrijven, maar wat ook belangrijk is als je onderzoek doet: kun je ook goed luisteren?" Koeno en Jan, jullie hebben me door de jaren heen vaker verrast met een onverwachte kijk op de zaak, en dat heb ik erg op prijs gesteld. Jan, je had altijd oog voor mij als mens, en niet alleen voor mij als promovenda die op tijd een proefschrift moest afleveren. Toen ik zwanger was, vertelde je uitgebreid over een van je aio's die een hele kinderschare op de wereld had gezet tijdens haar promotietraject en desondanks haar proefschrift had afgemaakt. Koeno, in elk gesprek zei je wel iets wat me langere tijd aan het denken zette. Je hebt een unieke en diepgaande manier van denken die ik heel waardevol heb gevonden.

Lia, op een van mijn eerste werkdagen na mijn zwangerschapsverlof kwam ik jou tegen op de gang van het FI. Ik had een halfjaar daarvoor één les bij jou geobserveerd en zag jou op grond van die ene les al als een wonderdocent. We raakten aan de praat over mijn aanstaande onderwijsexperiment en opeens hoorde ik je zeggen: "Die lessen wil ik wel geven." Ik weet nog dat ik thuis kwam en tegen Arthur zei: "Weet je nog die Lia Oosterwaal, die ene ongelooflijk goede docent? Die wil mijn onderzoekslessen wel geven!" Het was het begin van een ontzettend inspirerende samenwerking, die drie experimenten lang heeft voortgeduurd. Ik kan me geen bevlogener leerkracht voorstellen dan jij. En dat niet alleen: je hebt ook onderzoeksmatig een grote bijdrage geleverd door je goede ideeën, zinnige reflecties en eindeloze bereidheid (ook 's avonds laat) om mee te denken over alles wat bij de onderzoekslessen kwam kijken. Lia, bedankt

daarvoor. Als ik in de toekomst de kans krijg om nog een keer met je samen te werken, zal ik die kans zeker benutten.

Op het Freudenthal Instituut heb ik al die jaren mijn kamer gedeeld met Marjolijn en Jo. Marjolijn, wat was het fijn om jou als collega-aio te hebben. Je bevlogenheid, concentratie en toewijding waren aanstekelijk. Maar we konden het ook ontspannen hebben over de dagelijkse dingen, en praten over het leven na de aio-tijd. Jo, bedankt voor je interesse in mijn onderzoek door de jaren heen. Het was bijzonder om mijn kamer te delen met een echte Vygotsky-kenner. Maggie, ik vond het leuk en motiverend om jou te begeleiden bij je scriptieonderzoek en ik hoop dat we contact zullen houden. In verschillende fasen van mijn promotieonderzoek heb ik hulp gekregen van mensen op het Freudenthal Instituut. Frans, bedankt voor het meedenken over de lessen en het aandragen van goede ideeën. Nathalie, dank voor het corrigeren van de Engelstalige artikelen en je zorgvuldige hulp bij de *lay-out* van mijn proefschrift. Verschillende FI'ers hebben deelgenomen aan de expertondervraging die ik in hoofdstuk 3 beschrijf: bedankt daarvoor. Mariozee en Liesbeth, bedankt voor jullie ondersteuning bij het verwerken van data. Mark, wat fijn dat je hielp bij het opsnorren van artikelen en boeken die ik via de bieb niet in handen kon krijgen. Alle collega's die onderzoekspresentaties bijwoonden en vragen stelden, in de wandelgangen zinnige dingen zeiden, of anderszins motiverend waren: bedankt!

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Curriculum Vitae

Jantien Smit was born on April 21, 1976, in Monnickendam (the Netherlands) and completed her secondary education in 1994 at the Waterlant-College in Amsterdam. From 1994 to 1996 she combined the conservatory (violin) preliminary years at the University of Applied Sciences, Alkmaar, with a Bachelor in Dutch language and literature at the University of Amsterdam. In 2000 she obtained a Master's degree in Dutch language and literature, with a specialisation in argumentation theory, linguistic competence and rhetoric. Her thesis on fallacies was awarded a prize.

After her study Jantien fulfilled several language-oriented jobs, such as correcting newspaper articles and training adults in professional writing. She then started working as a primary teacher and simultaneously studied to obtain her teacher and Montessori degrees for primary teaching in 2004, at the University of Applied Sciences, Amsterdam. In 2004 Jantien was employed at Rainbow Montessori School in London, where she worked for several years.

In January 2008 Jantien started her PhD candidacy at the Freudenthal Institute for Science and Mathematics Education, Utrecht University. Her project, titled CLIMATE (Care for Language in Mathematics Teaching), was concerned with the teachers' role in realising language-oriented mathematics education. She presented her research at several national (e.g., *Onderwijs Research Dagen*) and international (e.g., EARLI and EARLI SIG10/21) conferences, for which she also (co)organised symposia. Jantien's research interests include scaffolding, classroom discourse, language-oriented teaching, multilingualism, mathematics education, and teachers' professional development.

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